



Application of Analytical Hierarchy Process (AHP) in Landslide Susceptibility Assessment of Zunheboto Sadar Block of Zunheboto District, Nagaland

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ABSTRACT

A landslide susceptibility mapping is created as a mitigation measure to lower the danger of a landslide and may be utilized for land use planning and management. Its goal is to identify the areas that are most vulnerable to landslides. Ten triggering elements were considered in the preparation of landslide susceptibility map using AHP modelling process: Aspect, Slope, Curvature, Stream Power Index, Landform map, Land use and Land cover, Slope forming material, Regolith thickness, Proximity to road, and Relative relief. After integrating the weights of each component, a map of the landslide susceptibility index (LSI) was produced. The LSI map was classified into three landslide prone zones: Low, Moderate, and High using Jenk's natural break classifier. Within the research area, 36.88% is categorized as a low susceptible zone, 47.04% falls within the moderate susceptible zone, and 16.07% is designated as a high susceptible zone. ROC (Receiver Operating Characteristics) plot technique was used to validate the precision of the map showing the risk of landslides and ROC plot shows an AUC of 0.85 indicating that the LSM generated has an accuracy of 85%. The landslide location data was used to confirm the analysis's findings. The validation findings demonstrated that the susceptibility map and the available information on the location of landslides agreed satisfactorily.

Keywords: Landslide, AHP, ROC, AUC, LSI,





INTRODUCTION

Landslides pose a significant natural hazard, particularly prevalent along ghat roads in mountainous regions, causing considerable losses in human lives, property, and infrastructure. The resulting damages, amounting to hundreds of billions of dollars, encompass both direct financial losses and environmental impacts, making it a recurring and impactful phenomenon [1]. It is feasible to identify regions vulnerable to slope failures by looking at the spatial distribution data of previous landslides and the factors causing them. These insights can be conveyed by generating landslide susceptibility maps. A map indicating landslide susceptibility identifies areas expected to face landslides in the future. This is accomplished by establishing correlations between crucial factors contributing to landslides and the historical occurrence of slope failures [2]. Generating landslide susceptibility maps depends on a nuanced comprehension of the slope movements and the governing factors. The reliability of these susceptibility maps primarily relies on the quantity and quality of the available data, the selected scale of analysis, and the appropriate modelling methodology. The creation of these maps involves the utilization of various qualitative or quantitative approaches [3]. The aim of this investigation is to generate Landslide Susceptibility Map using AHP modelling with ten causative factors. This map will serve as a proactive measure to mitigate the risk of landslides, providing valuable information for management of land use and its planning in Zunheboto Sadar.

Study Area

The research site, Zunheboto Sadar Block (*figure 1*) is located between 94°27'54.85" and 94°37'20.61" longitude, 25°56'42.93" and on 26°06'15.44" latitudes, spans an expanse of 123.43 km² and is situated in the Zunheboto district of Nagaland State. Positioned at the core of Zunheboto district, it serves as the focal point where the majority of the district's population is concentrated. The primary rivers within the research area include the Langki river lying to the east and the Tizu river lying to the west of the study area. The terrain is characterized by mountains and high altitude, ranging from 642 m to 1989 m. In adapting to the hilly landscape, the residents primarily rely on Jhum cultivation, which poses a significant environmental threat. The rocks in the research area are classified under the Barail Group and the Disang Group. The Disang Group, which comprises the majority of the area, is the older lithounit. It is distinguished by a significant, consistent sequence of splintery and nodular grey shale, occasionally interspersed with sandstone, siltstone, and localized intraformational conglomerate beds [4]. The Barail group comprises extensive sequences of sandstone alternating with thin shale layers, dating from the Upper Eocene to Oligocene. Positioned above the Disang Group, the Barail Group is identified by lithounits within the Laisong Formation, showcasing multilayered sandstones interspersed with variable shale-siltstone interbands [5].

Landslide Inventory

A thorough and accurate landslide inventory map document contains crucial details about slope failures, including their location, size, characteristics, kind of movement, estimated age, and other factors. This information is crucial for studies focused on the geographical dispersion of landslides. Lately, the Google Earth platform has been extensively employed in landslide investigations [6]. The study area's landslide data is sourced from literature and fieldwork. The landslide inventory in the study area includes details about the landslide's location, triggering factors, activity, type, classification, and the geological characteristics of the failed mass. A total number of 136 landslides were recorded from the research area.

MATERIALS AND METHODS

The Survey of India toposheets, field surveys, and satellite data provided the data required for this investigation. ALOS Palsar DEM having a resolution of 12.5 m was utilized to generate various thematic layers such as slope, aspect, curvature, stream power index, relative relief and landform map. Lithology has been integrated into the Slope Forming Material map through outcrop mapping. The Land Use and Land Cover layer was created using LANDSAT 8 and Google Earth imagery. Landslide data was digitized from Google Earth with comprehensive field validation.





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Analytical Hierarchy Process

The Analytical Hierarchy Process (AHP) was used to generate the Landslide Susceptibility Map which was introduced by Saaty is widely recognized methodology based on the additive weighting model. This semi-qualitative method evaluates the contributions of several factors to landslide occurrence through pairwise comparisons based on a matrix. In this study, the weights for each criterion (thematic layers) are established through a pairwise comparison matrix, following the methodology outlined by Saaty[7]. Thematic layers associated with causative factors were created through the use of GIS technologies, field surveys, and remotely sensed data. The Analytical Hierarchy Process has several disadvantages in addition to benefits when it comes to rating and weighting the factors. The knowledge of an individual or professional has a significant influence on the relative scoring of factors. The subjective nature of assigning preferences to factors by an individual or professional is often not universally recognized, posing a significant limitation in any method of making subjective decisions. However, the pairwise comparison method offers a simple and reasonable decision rule. In landslide studies, certain factors exhibit a degree of interdependence in causing landslides while the Analytical Hierarchy Process (AHP) treats factors in a hierarchical manner as independent entities [8]. It is required to create a pair-wise comparison matrix with scores as shown in Table 3 in order to calculate factor weights in AHP. Each element is compared to all other factors while creating a pair-wise comparison matrix by allocating a relative dominance value, which ranges from 1 to 9, to the intersecting cell. The value ranges from 1 to 9 shown in Table 2, indicating that the vertical axis factor is valued higher than the horizontal axis factor and on the other hand, the value falls between the reciprocals 1/2 and 1/9 if the component on the horizontal axis is thought to be more significant [9].

Matrix calculations yield factor/class weights expressed as eigenvectors, and the computation of the maximum eigenvalue is an integral component of the AHP model. The transitivity rule may be violated by subjective decision-making, leading to inconsistencies [10]. In this study, the relative value of every factor/class pair was established based on expert knowledge acquired from fieldwork and the occurrence of landslides in those classes.

In this hierarchical classification approach, the coherence of our method can be assessed by calculating consistency ratio (CR) as defined by Equation (1). The consistency ratio serves as an acceptance test for the weights assigned to various criteria[11]. The purpose of this step is to find any discrepancies between the weights assigned to each pair of criteria. The Consistency Ratio (CR) serves as a quantitative indication of the degree of consistency in decision-making, with its calculation based on Equation (1).

$$CR = CI/RI \dots\dots\dots eqn (1)$$

Here, the consistency index is denoted by CI and the random consistency index by RI, as defined in Equation (2).

$$CI = (\lambda_{max} - 1)/(n - 1) \dots\dots\dots eqn (2)$$

where n is the matrix's order and λ max is the principal eigenvalue, which is determined from the matrix. Saaty states that an imprecision of less than 10% is indicated by a consistency ratio of ≤10%. The idea is to compare the elemental weights at random with the judgment. Landslide susceptibility map for the research area was ultimately created by summing the weight of each factor multiplied by the class weight (or rating) of each corresponding factor for that specific pixel, expressed as follows:

$$LSI = \sum_{i=0}^n (Wi \times Ri) \dots\dots\dots eqn (3)$$

where Wi stands for the weights allocated to each of the landslide conditioning variables, Ri stands for the rating classes for each layer, and LSI stands for the intended landslide susceptibility index for the given pixel. Using the natural break feature in ArcGIS, the LSI map was divided into groups for low, moderate, and high susceptibility, as seen in figure 3.



**Khekuto Kiho and Asha Manjari****CAUSATIVE FACTORS OF LANDSLIDE**

Ten factors (*figure 2 a to j*) were taken into account in the modelling of Landslide susceptibility map of the research area. The DEM derivatives maps are Slope, Aspect, Landform, SPI, Curvature and Relative Relief map that was produced using 12.5 m spatial resolution of ALOS PALSAR DEM data in ArcMap 10.8. The Causative factors used are as follows

Slope

Slope gradient has a major impact on the frequency of landslides *figure 2(a)*, a crucial factor that directly affects slope stability by influencing shear force. The slope map that was generated was then categorized into ten classes including 0-5°, 05-10°, 10-15°, 15-20°, 20-25°, 25-30°, 30-35°, 35-40°, 40-45° and >45°. Within the research area, the Slope of 25-30° constitutes 24% of the maximum coverage followed by 20-25° encompassing 19.87%, and 30-35° accounting for 17.56%.

Aspect

Slope aspect indicates which way the terrain's steepest slope is oriented. This directional influence, because of its significant effects on soil strength, moisture retention, and vegetation cover, can play a crucial role in initiating landslides [12]. The slope aspect was classified into nine classes namely South (157.5–202.5°), Southwest (202.5–247.5°), West (247.5–292.5°), Northeast (22.5–67.5°), East (67.5–112.5°), Southeast (112.5–157.5°), North (337.5–360° and 0–22.5°), and Northwest (292.5–337.5°). The aspect map is shown in *figure 2(b)*. Southeast covers the maximum area of 16.67% of the study area followed by East 15.11% and West 12.10%. Flat covers the least area 0.63% of the study area followed by North East 9.9%.

Landform

The automated landform classification utilized the geomorphon module in GRASS GIS, generated by ALOS PALSAR DEM with a 12.5 m resolution. The geomorphon method employs topographic pattern recognition, utilizing only the DEM as input data. In summary, the algorithm assesses the focus cell in eight principal directions, determining whether the neighboring cells are higher, lower, or at the same elevation. Based on the pattern of these neighboring cells, the algorithm assigns one of the ten general landform labels to the focal cell [13]. The landform map is classified into Slope, Spur, Hollow, Valley, Ridge, Summit, Foothlope, Depression, Flat and Shoulder. Slope covers the maximum area with 54.19% followed by spur 19.66%, hollows 16.88% and valley 5.03%. The landform map of the research site is shown in *figure 2(c)*.

Stream Power Index

The erosive strength of streams in a terrain is represented by the Stream Power Index (SPI). It is calculated by using formula given by $SPI = \ln(CA \times \tan Slp)$, where Slp denotes the slope gradient and CA denotes the catchment area. The Stream Power Index (SPI) considers both the local slope gradient and catchment area, thereby incorporating the proportional discharge or erosive power of the drainage. This secondary attribute DEM-derived map provides a quantification of the erosive power of flowing water [14]. SPI is classified into 5 classes—Very low erosion, Low erosion, Moderate erosion, High erosion, and Very high erosion—were attained shown in *figure 2(d)*. In the study area, very low Erosion covers maximum area as 27.41%, followed by Moderate Erosion covering 21.55% and Very High Erosion 21.28%. Low erosion covers the least of 13.22% followed by High Erosion 16.51%.

Proximity to roads

The proximity to roads is a significant anthropogenic factor that affects the incidence of landslides. Indeed, while conducting fieldwork, numerous landslides attributable to road construction activities were identified. In the current study as seen in *figure 2(e)*, the buffer 0-20 m accounts for 911.05 Ha, accounting for 7.3% of the study area.

Land use and Land cover

The distribution of landslides is significantly influenced by land cover, with forested areas typically experiencing fewer landslides compared to barren areas. The identified classes within the LULC theme include Jhum Cultivation,





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Moderately Dense Forest, Open Forest, Settlement, Shrub, Terrace Cultivation, Very Dense Forest and Water Bodies. In the study area, very dense forest accounts for 44.9%, Moderately dense forest accounts for 31.06%, Open Forest accounts for 13.49%, Jhum cultivation for 1.72%, Settlement for 5.88%, Shrub for 0.17%, Terrace cultivation for 2.28% and water bodies accounting 0.45%. The LULC map is shown in *figure 2(f)*.

Curvature

Curvature shown in *figure 2(g)* symbolizes the surface's second derivative and the slope's shape significantly contributes to landslide occurrence, exerting a substantial influence on slope instability. For surface convexity, a positive curvature value is indicated, Concavity is indicated by a negative value, and a curvature value of 0 indicates a flat surface. In landslide hazard zoning, curvature serves as an oblique measure of the effects of water [15]. It was divided into three categories flat, convex, and concave curvature using total curvature. Convex area covers 40.72%, Concave covers 41.41% and Flat covers 17.86% of the study area.

Relative Relief

Relative relief seen in *figure 2(h)* reflects the influence of vegetation changes in relation to elevation. The variation in elevation, as indicated by the relative relief affects the natural conditions influencing landslide occurrence [16]. Relative relief in the research area is classified in four classes, they are 0-550 m, 550-650 m, 650-750 m and >750 m. Out of this 650-750 m covers the maximum area of 43% of the study area followed by 550-650 m covering area of 48%.

Regolith Thickness

The process of rock weathering near the Earth's surface results in the formation of regolith. Regolith is a layer comprising saprolite, weathered rock and soil, containing fractures, pores, and weathered minerals. This layer serves as a vital interface supporting life between the bedrock and the ecosystems above it [17]. The regolith in the study area was delineated and categorized into four classes: <0.5m, 0.5-2m, 2-5m, and >5m, seen in *figure 2(i)*. The thickness is influenced by various factors, with local variations in terrain morphology being particularly significant. Consequently, predicting regolith thickness over a large area becomes challenging due to this complexity. In the study area regolith thickness of 0.5- 2 m has the maximum area of 59.6% of the total area followed by < 0.5 m covering 28.8% of the study area. The class >5 m covers the least area of 0.89% and the class >5 m covers 10.53% of the total area.

Slope Forming Material:

Slope Forming Material (SFM) shown in *figure 2(j)* heavily relies on the characteristics of the type of material present on the slope. The spatial distribution and depth of this material play a pivotal role in triggering various types of landslides. The SFM map is created using Geology, Land Use and Land Cover (LULC), and Geomorphology maps as the base, incorporating field inputs in accordance with the guidelines outlined by the Geological Survey of India. Slope Forming Material were classified as Loose debris, Flaggy sandstone with subordinate shale and Siltstone, Compact debris, Disang Shale, Colluvium, Transported soil, Barial Sandstone, In situ Soil, Alluvium and water bodies. Area having regolith thickness of < 0.5 m was classified under rock domain. In-situ soil covers the maximum of 36.87% of the area followed by Disang Shale 23.89%, which is also the major in rock domain. Barial Sandstone covers 3.15% and Flaggy sandstone with subordinate shale and Siltstone covers 1.73% of the study area.

RESULT AND DISCUSSION

The higher the index, the more vulnerable the area is to landslides since the LSI measures the relative susceptibility of a landslide occurrence. Applying the concept of AHP, the LSI values were calculated using Equation (3) and the LSI had an average value of 12.37 and a standard deviation of 3.32, with a minimum value of 3.32 and a maximum value of 33.86, according to the computation. Three distinct zones on the landslide susceptibility map were categorized based on the Jenk's natural breaks range on the LSI values. These are Low, Moderate and High Susceptibility Zones shown in *figure 3* along with the landslide location points. Within the study area, the proportion



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of total area falling under Low, Moderate, and High susceptibility zones is 36.88%, 47.04%, and 16.07%, respectively (Table 4). In aspect SE direction falls maximum in both High and moderate Susceptibility zone accounting for 446 Ha in High Susceptibility zone and 790 Ha in moderate Susceptibility zone. In curvature, 826 Ha of concave class falls in High Susceptibility zone and 815 Ha of convex falls in High Susceptibility zone. In Landform, Slope class falls highest in both High and moderate susceptibility zone of 1161 Ha and 3518 Ha respectively. In LULC, 718 Ha of Moderately Dense Forest, 112 Ha of Jhum cultivation and 164 Ha of Settlement falls in High Susceptibility zone. In Relative Relief, 940 Ha and 2627 Ha of 650- 750 m class falls in High and Moderate susceptibility zone respectively. In slope, 1864 Ha and 957 Ha of 25-30° class falls under Moderate and High Susceptibility zone respectively. Within the susceptibility zones, 1478 Ha of the 30-35° class fall under the category of Moderate susceptibility, while 391 Ha belong to the zone of high susceptibility. In the stream power Index, Very High Erosion class accounts 1348 Ha and 618 Ha in Moderate and High Susceptibility zone respectively. In Slope forming Material, Insitu soil and Disang shale accounts for 514 Ha and 526 Ha in High susceptibility zone respectively. 677 Ha of 0.5 m class in Regolith thickness falls under High Susceptibility zone and 373 Ha of 2-5 m class fits inside the zone of high susceptibility. The reason for high Susceptibility in 0.5 m class is due to the presence of Disang Shale, which is prone to weathering and erosion, and contribute to slope instability. In proximity to road, 0-20 m class accounts for 556 Ha under High Susceptibility zone and 389 Ha of 20-50 m class falls under High Susceptibility zone. Central and Southern part of the study area more heavily in areas of high susceptibility compared to the northern part of the study area.

Validation

The accuracy of the map is a measure of its capacity to differentiate between landslide-free and landslide-susceptible areas. Additionally, comparing several models and model parameter values is made possible by validation. The precision and objectivity of a model hinge on factors such as model accuracy, input data quality, the expertise of professionals involved, and the size of the study area [18]. The ROC (Receiver Operating Characteristics) plot approach was employed in this work to verify the landslide susceptibility map's accuracy. The ROC curve method is based on the misclassification of current landslide areas, specifically False Positives, and the misclassification of non-landslide areas, referred to as False Negatives [19]. 25% of the landslide location were chosen randomly for testing after which ROC curve and AUC were generated using ROC tool from ArcGIS platform. ROC curve (figure 4) displays an AUC of 0.858, meaning that the generated LSM has an accuracy of 85%.

CONCLUSION

Based the results shown in Table 3, the weightage of the Landslide causative factors are as follows: SFM (0.28), Slope (0.20) LULC (0.14), Road (0.106), Regolith (0.07), Relative relief (0.05), Stream Power Index (0.05), Landform (0.03), Aspect (0.02) and Curvature (0.01). The findings have shown that areas in close proximity to the road mainly fall within the high susceptibility zone, primarily attributed to slope cuts made for road construction. Most of the Settlement areas have been identified within zones of moderate to high susceptibility zone. Loose debris has a high correlation with high susceptibility zone. The high relative reliefs observed in the study area represents surface features like cliffs and ridges, which are frequently prone to instability because of the effects of triggering variables like earthquakes and rains. The Disang grey shale can retain water and becomes weaken, upon drying, it contracts and fractures into friable pellet-like structures that align parallel to the bedding. As this shale fractures it become prone to landslide in the sloping areas. In regions featuring Flaggy sandstone with subordinate shale and siltstone, and where its bedding aligns parallel to the slope, the upper beds typically slide down the slope along the bedding plane due to the differential weathering of shale, sandstone and siltstone. Validation was performed using ROC curve and gave an acceptable success rate accuracy of 85%.

REFERENCES

1. Aleotti P, Chowdhury R (1999) Landslide hazard assessment: summary review and new perspectives. Bull Eng Geol Env;58(1):21-44.



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2. Brabb, E.E. Innovative approaches to landslide hazard and risk mapping. Proc., Fourth International Symposium on Landslides, vol. 1. Canadian Geotechnical Society, Toronto, Canada, 1984;307–324.
3. Yalcin A. GIS-based landslide susceptibility mapping using analytical hierarchy process and bivariate statistics in Ardesen (Turkey): comparisons of results and confirmations. *catena*. 2008;72(1):1-2.
4. Mallet FR. On the coal fields of Naga hills bordering the Lakhimpur and Sibsagar districts. *Assam. Mem. Geol. Surv. India*. 1876;12(2):166-363.
5. Agrawal OP, Ghose NC. Geology and stratigraphy of the Naga Hills ophiolite between Melluri and Awankhoo, Pheek District, Nagaland, India. In Indian chapter IGCP Projects 195 and 197. Meeting 1986;(63-195).
6. Zhang J, Gurung DR, Liu R, Murthy MS, Su F. Abe Barek landslide and landslide susceptibility assessment in Badakhshan Province, Afghanistan. *Landslides*. 2015;12:597- 609.
7. Saaty TL. How to make a decision: the analytic hierarchy process. *European journal of operational research*. 1990;48(1):9-26.
8. Kumar R, Anbalagan R. Landslide susceptibility mapping using analytical hierarchy process (AHP) in Tehri reservoir rim region, Uttarakhand. *Journal of the Geological Society of India*. 2016;87:271-86.
9. Chapter 4. Saaty, Thomas L. Fundamentals of decision making and priority theory with the analytic hierarchy process. Vol. 6. RWS publications, 2001. P. 65-69.
10. Feizizadeh B, Blaschke T. GIS-multicriteria decision analysis for landslide susceptibility mapping: comparing three methods for the Urmia lake basin, Iran. *Natural hazards*. 2013;65:2105-28.
11. Saaty TL. A scaling method for priorities in hierarchical structures. *Journal of mathematical psychology*. 1977;15(3):234-81.
12. Dai FC, Lee CF, Ngai YY. Landslide risk assessment and management: an overview. *Engineering geology*. 2002;64(1):65-87.
13. Jasiewicz J, Stepinski TF. Geomorphons—a pattern recognition approach to classification and mapping of landforms. *Geomorphology*. 2013;182:147-56.
14. Conforti M, Aucelli PP, Robustelli G, Scarciglia F. Geomorphology and GIS analysis for mapping gully erosion susceptibility in the Turbolo stream catchment (Northern Calabria, Italy). *Natural hazards*. 2011;56:881-98.
15. Gadtaula A, Dhakal S. Landslide susceptibility mapping using weight of evidence method in Haku, Rasuwa district, Nepal. *Journal of Nepal Geological Society*. 2019;58:163-71.
16. Singh K, Kumar V. Hazard assessment of landslide disaster using information value method and analytical hierarchy process in highly tectonic Chamba region in bosom of Himalaya. *Journal of Mountain science*. 2018;(4):808-24.
17. Graham R, Rossi A, Hubbert R. Rock to regolith conversion: Producing hospitable substrates for terrestrial ecosystems. *GSA today*. 2010;20:4-9.
18. Soeters R, Van Westen CJ. Slope instability recognition, analysis and zonation. *Landslides: investigation and mitigation*. 1996;247:129-77.
19. Centor RM, Schwartz JS. An evaluation of methods for estimating the area under the receiver operating characteristic (ROC) curve. *Medical Decision Making*. 1985;5(2):149- 56.





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Table 1. Random consistency index (RI) [17]

Number of criteria	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.53	1.56	1.57	1.58

Table 2. Ordinal scale represents preference of judgement [17]

Preference/ordinal scale	Degree of Preference	Remarks
1	Equally	Two activities contribute equally to the objective.
3	Moderately	Experience and judgment slightly to moderately favour one activity over another.
5	Strongly	Experience and judgment strongly or essentially favour one activity over another.
7	Very Strongly	An activity is strongly favoured over another and its dominance is showed in practice.
9	Extremely	The evidence of favouring one activity over another is of the highest degree possible of an affirmation.
2,4,6,8	Intermediate	Used to represent compromises between the preferences in weights 1, 3, 5, 7 and 9
Reciprocals	Opposites	Used for inverse comparison.

Table 3. Refers AHP scores of factors/classes, eigenvector, CR and Maximum eigen value

FACTOR AND CLASSES												Normalized Eigen (Weight)
FACTOR COMPARISON	1	2	3	4	5	6	7	8	9	10		
Slope Forming Material (1)	1											0.289
Slope(2)	1/2	1										0.209
Land Use and Land Cover (3)	1/3	1/2	1									0.149
Road (4)	1/4	1/3	1/2	1								0.106
Regolith Thickness (5)	1/5	1/4	1/3	1/2	1							0.074
Relative Relief (6)	1/6	1/5	1/4	1/3	1/2	1						0.05
Stream Power Index (7)	1/6	1/5	1/4	1/3	1/2	1	1					0.05
Landform (8)	1/7	1/6	1/5	1/4	1/3	1/2	1/2	1				0.034
Aspect (9)	1/8	1/7	1/6	1/5	1/4	1/3	1/3	1/2	1			0.024
Curvature (10)	1/9	1/8	1/7	1/6	1/5	1/4	1/4	1/3	1/2	1		0.017
CR=0.05 Maximum eigenvalue = 10.64												
FACTOR CLASSES COMPARISON												
Landform												
Depression (1)	1											0.232
Hollow (2)	1	1										0.232
Slope (3)	1/2	0.5	1									0.158
Spur (4)	1/3	1/3	1/2	1								0.107
Ridge (5)	1/4	1/4	1/3	1/2	1							0.069
Shoulder (6)	1/5	1/5	1/4	1/3	1/2	1						0.04
Footslope (7)	1/5	1/5	1/4	1/3	1/2	1	1					0.04





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Valley (8)	1/5	1/5	1/4	1/3	1/2	1	1	1			0.04
Flat (9)	1/5	1/5	1/4	1/3	1/2	1	1	1	1		0.04
Summit (10)	1/5	1/5	1/4	1/3	1/2	1	1	1	1	1	0.04
CR= 0.012 Maximum eigenvalue = 10.174											
Aspect											
SE (1)	1										0.262
S (2)	1/2	1									0.168
SW (3)	1/2	1	1								0.168
N (4)	1/3	1/2	1/2	1							0.102
E (5)	1/3	1/2	1/2	1	1						0.102
NE (6)	1/4	1/3	1/3	1/2	1/2	1					0.061
W (7)	1/4	1/3	1/3	1/2	1/2	1	1				0.061
NW (8)	1/5	1/4	1/4	1/3	1/3	1/2	1/2	1			0.038
Flat (9)	1/5	1/4	1/4	1/3	1/3	1/2	1/2	1	1		0.038
CR= 0.01 Maximum eigenvalue = 9.142											
Regolith											
>5 m (1)	1										0.558
2-5 m (2)	1/3	1									0.263
0.5-2 m (3)	1/5	1/3	1								0.122
< 0.5 m (4)	1/7	1/5	1/3	1							0.057
CR= 0.07 Maximum eigenvalue = 4.17											
Slope Forming Material											
Loose Debrree (1)	1										0.301
Flaggy sandstone with subordinate Shale and Siltstone (2)	1/2	1									0.221
Compact Debrree (3)	1/4	1/3	1								0.115
Disang Shale (4)	1/4	1/3	1	1							0.115
Colluvium (5)	1/5	1/4	1/2	1/2	1						0.079
In situ Soil (6)	1/6	1/5	1/3	1/3	1/2	1					0.054
Barial Sandstone (7)	1/7	1/6	1/4	1/4	1/3	1/2	1				0.035
Transported Soil (8)	1/7	1/6	1/4	1/4	1/3	1/2	1	1			0.035
Alluvium (9)	1/8	1/7	1/5	1/5	1/4	1/3	1/2	1/2	1		0.023
Water Bodies (10)	1/8	1/7	1/5	1/5	1/4	1/3	1/2	1/2	1	1	0.023
CR= 0.04 Maximum eigenvalue = 10.54											
Land Use and Land cover											
Shurb (1)	1										0.346
Jhum Cultivation (2)	1/2	1									0.248
Moderately Dense Forest (3)	1/4	1/3	1								0.123
Open Forest (4)	1/5	1/4	1/2	1							0.078
Settlement (5)	1/5	1/4	1/2	1	1						0.078
Terrace Cultivation (6)	1/6	1/5	1/3	1/2	1/2	1					0.048
Very Dense Forest (7)	1/6	1/5	1/3	1/2	1/2	1	1				0.048
Water Bodies (8)	1/7	1/6	1/4	1/3	1/3	1/2	1/2	1			0.031





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CR= 0.03 Maximum eigenvalue = 8.28											
Stream Power Index											
Very high Erosion (1)	1										0.441
High Erosion (2)	1/2	1									0.291
Moderate Erosion (3)	1/4	1/3	1								0.131
Low Erosion (4)	1/5	1/4	1/2	1							0.083
Very Low Erosion (5)	1/6	1/5	1/3	1/2	1						0.054
CR= 0.03 Maximum eigenvalue = 5.14											
Proximity to Road											
0-20 m (1)	1										0.524
20-50 m (2)	1/3	1									0.288
50-250 m (3)	1/7	1/5	1								0.09
250-700 m (4)	1/8	1/6	1/2	1							0.059
>700 m (5)	1/9	1/7	1/3	1/2	1						0.039
CR= 0.07 Maximum eigenvalue = 5.32											
Relative Relief											
>750 m (1)	1										0.598
650-750 m (2)	1/4	1									0.209
550-650 m (3)	1/5	1/2	1								0.133
0-550 m (4)	1/7	1/4	1/3	1							0.06
CR= 0.06 Maximum eigenvalue = 4.16											
Curvature											
Convex	1										0.639
Concave	1/3	1									0.274
Flat	1/6	1/4	1								0.087
CR= 0.07 Maximum eigenvalue = 3.07											
Slope											
25-30°	1										0.276
30-35°	1/2	1									0.194
20-25°	1/3	1/2	1								0.132
35-40°	1/3	1/2	1	1							0.132
40-45°	1/4	1/3	1/2	1/2	1						0.09
>45°	1/5	1/4	1/3	1/3	1/2	1					0.063
15-20°	1/6	1/5	1/4	1/4	1/3	1/2	1				0.044
10-15°	1/7	1/6	1/5	1/5	1/4	1/3	1/2	1			0.03
05-10°	1/8	1/7	1/6	1/6	1/5	1/4	1/3	1/2	1		0.021
0-5°	1/8	1/7	1/6	1/6	1/5	1/4	1/3	1/2	1	1	0.021
CR= 0.04 Maximum eigenvalue = 10.52											

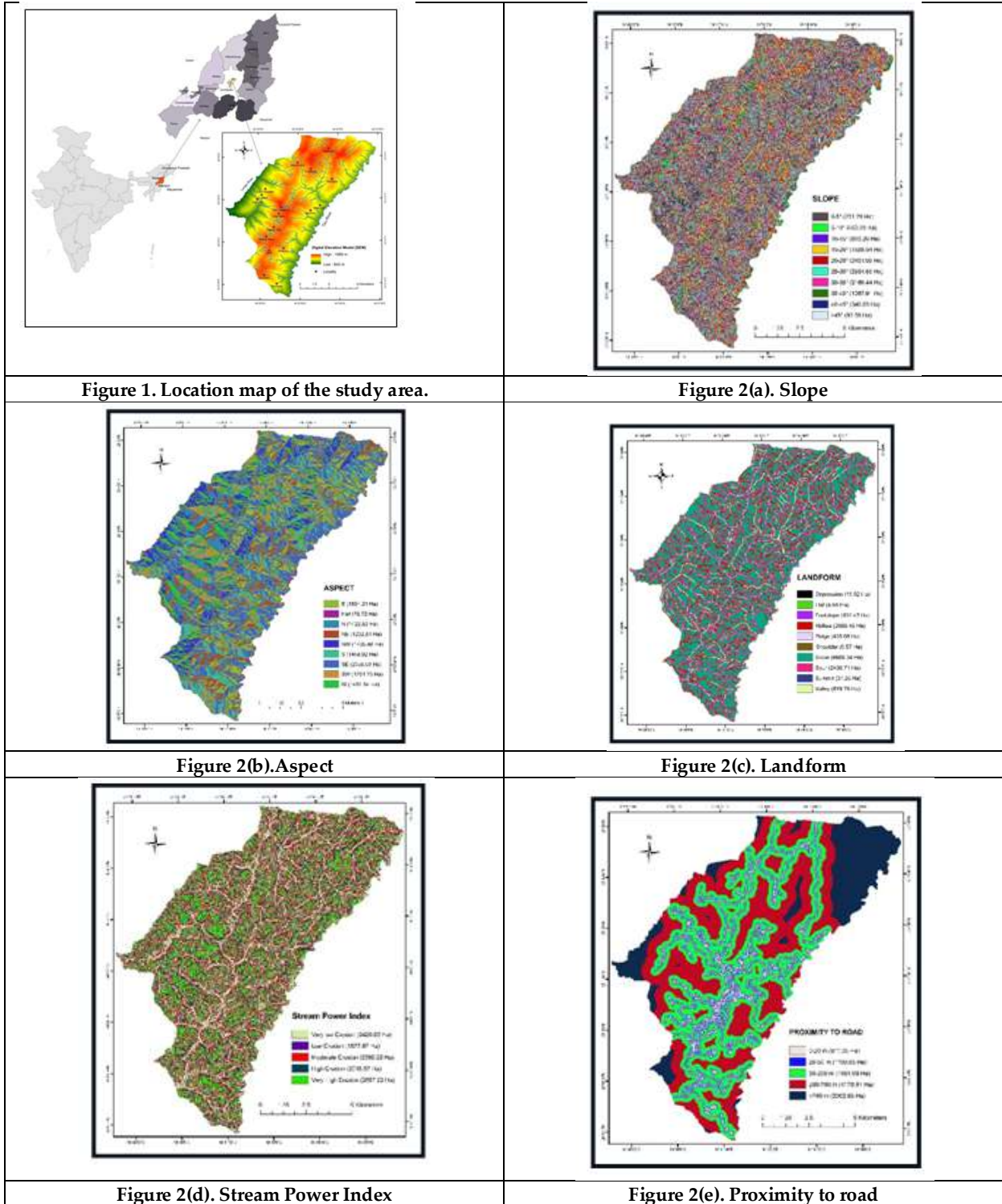
Table 4. Landslide Susceptibility classes with area coverage

Susceptible Class	Area sq.km	Area coverage %	No. of Landslide	Landslide %	Density of landslide
Low	45.492	36.88	4	2.94	0.08
Moderate	58.024	47.04	38	27.94	0.65
High	19.825	16.07	94	69.11	4.74





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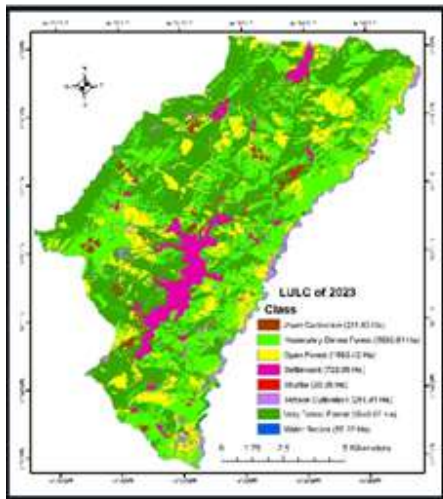


Figure 2(f). LULC

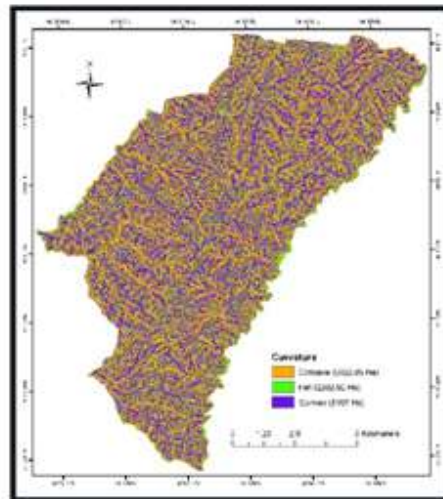


Figure 2(g). Curvature

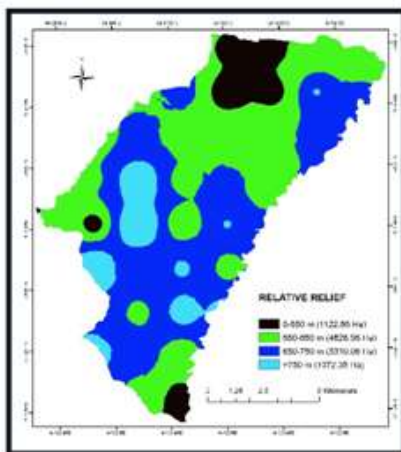


Figure 2(h).Relative relief

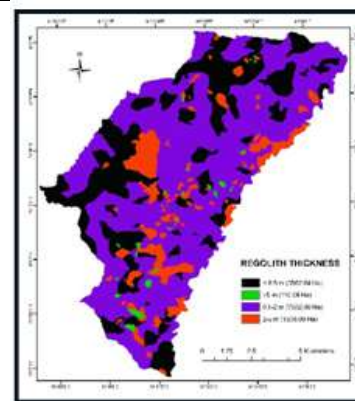


Figure 2 (i).Regoliththickness

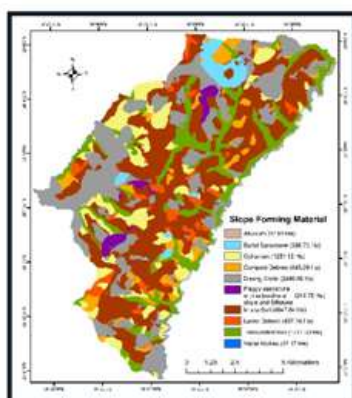


Figure 2 (j). Slope forming material

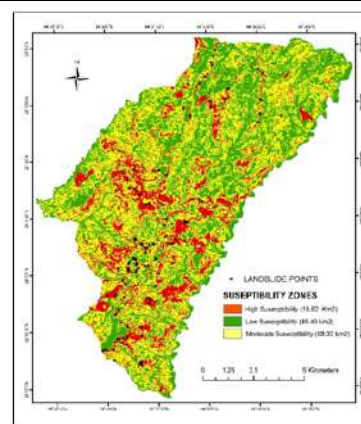


Figure 3. Landslide susceptibility zones with landslide location





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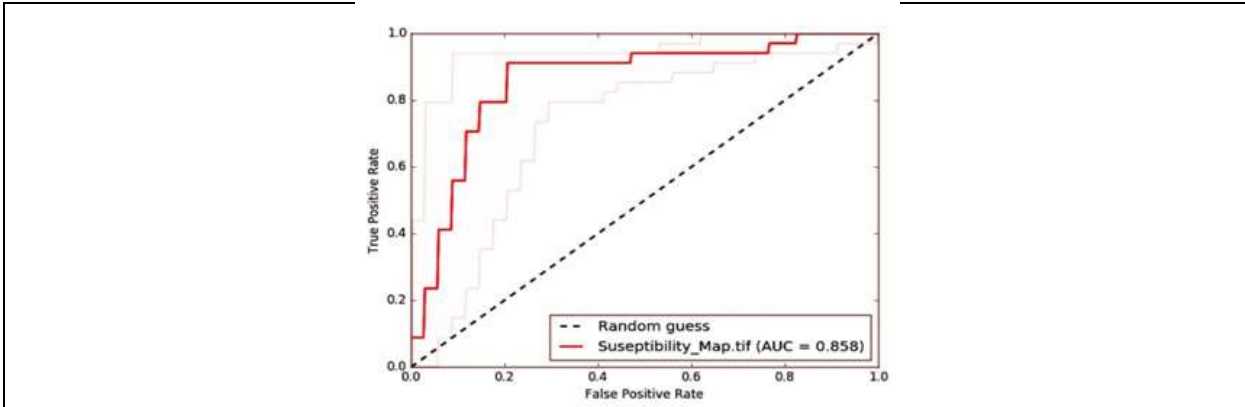


Figure 4. ROC Curve for Validation





Using Hybrid Machine Learning Methods to Predict Plant Disease on Soil Conditions

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ABSTRACT

This research addresses the critical challenge of predicting plant diseases based on soil conditions by employing a hybrid machine learning approach. Traditional methods often overlook the complex interplay between soil factors and disease onset. In this study, a comprehensive dataset encompassing soil parameters and plant health labels is utilized. The proposed hybrid model integrates supervised techniques, including Random Forest and Support Vector Machines, with unsupervised methods such as K-Means clustering. Through extensive experimentation and evaluation, our model demonstrates superior accuracy in predicting plant diseases compared to conventional approaches. The findings underscore the pivotal role of specific soil conditions in disease prediction. This research not only contributes to advancing agricultural practices but also sets the stage for future investigations into real-time sensor integration and user-friendly applications for farmers, thereby revolutionizing crop management strategies.

Keywords: Plant disease prediction, soil conditions, hybrid machine learning, supervised learning, unsupervised learning, agriculture, crop health.



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INTRODUCTION

In recent years, the agricultural sector has witnessed a growing interest in leveraging advanced technologies to improve crop yield and mitigate the impact of plant diseases. One crucial aspect of this endeavor is the integration of machine learning methods to predict plant diseases based on soil conditions. This approach offers a holistic understanding of the complex interactions between soil properties and the onset of diseases, enabling early detection and effective management strategies. This introduction provides an overview of the significance of employing hybrid machine learning methods in predicting plant diseases and emphasizes the importance of considering soil conditions in these predictive models. Agriculture is a vital component of global food security, and the health of crops is directly influenced by various factors, including soil conditions. Plant diseases pose a significant threat to crop productivity, leading to substantial economic losses and affecting food supply chains. Soil properties such as moisture content, nutrient levels, and pH play a crucial role in determining the susceptibility of plants to diseases. Understanding the dynamic relationship between soil conditions and plant health is essential for developing accurate predictive models[1]. Machine learning techniques have shown remarkable success in various fields, and their application in agriculture holds immense potential. Predictive modeling using machine learning allows for the analysis of large datasets, enabling the identification of patterns and trends that may be imperceptible through traditional methods[2]. Hybrid machine learning methods combine multiple algorithms or models to enhance prediction accuracy and robustness. Integration of diverse techniques, such as ensemble methods (e.g., Random Forest, Gradient Boosting), deep learning, and traditional statistical models, can provide a comprehensive understanding of the complex relationships within agricultural systems[3]. Despite the promise of machine learning in agriculture, challenges exist, including the need for high-quality data, interpretability of models, and addressing the dynamic nature of agricultural ecosystems. Opportunities lie in the potential for real-time monitoring, precision agriculture, and customized disease management strategies based on soil and environmental conditions. The integration of hybrid machine learning methods for predicting plant diseases based on soil conditions represents a cutting-edge approach in agriculture. By considering the intricate relationships between soil properties and plant health, these models contribute to more accurate and timely disease predictions, ultimately supporting sustainable and efficient crop management practices.

OBJECTIVES

1. To develop a predictive model for plant diseases based on soil conditions using hybrid machine learning.
2. Emphasize the potential benefits for farmers in early disease detection and management.

LITERATURE REVIEW

Review existing studies on plant disease prediction and their reliance on soil-related factors. Evaluate the limitations of traditional approaches and the potential advantages of hybrid machine learning methods. Agricultural productivity is closely linked to the health of crops, and the early detection of plant diseases is essential for effective disease management. Recent advancements in machine learning (ML) have opened new avenues for predicting plant diseases, particularly by integrating hybrid ML methods that consider both soil conditions and plant health. Soil conditions significantly influence plant health, with parameters such as moisture content, nutrient levels, and pH playing crucial roles. Understanding these interactions is vital for developing accurate predictive models[4]. Machine learning techniques, including supervised and unsupervised learning, have shown promise in agriculture. These models enable the analysis of large datasets, providing insights into complex relationships within agricultural ecosystems. The integration of ensemble methods, such as Random Forest and Gradient Boosting, enhances prediction accuracy by combining multiple models[5]. Deep learning models, including neural networks, have demonstrated success in image-based plant disease detection, offering a valuable tool for comprehensive analyses[6]. Traditional statistical models, when combined with machine learning techniques, contribute to a holistic understanding of the relationships between soil conditions and plant diseases. High-quality, representative datasets





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are crucial for training accurate models, and obtaining such data remains a challenge in agriculture. The interpretability of complex hybrid models is a concern, but efforts are being made to develop models that provide transparent insights into decision-making processes. The dynamic nature of agricultural ecosystems poses challenges in developing models that can adapt to changing conditions. Research [7] utilized neutron radiography to monitor water flow into the roots of plants in real-time, showcasing the potential for precise monitoring of soil-plant interactions. Hybrid machine learning methods present a promising avenue for predicting plant diseases based on soil conditions. By combining diverse models, these approaches offer a more comprehensive understanding of the complex relationships within agricultural systems, paving the way for improved disease management strategies.

PROPOSAL METHOD

Machine learning excels in analyzing data related to soil conditions, encompassing factors like moisture levels, temperature, and chemical composition, all crucial for crop growth and livestock well-being. In modern agriculture, this capability allows for highly precise cultivation, enabling farmers to address the needs of individual plants and animals, thereby significantly enhancing decision-making effectiveness. Leveraging machine learning enables the prediction of harvest yields, assessment of crop quality for specific plant species, and the detection of crop diseases and weed infestations, tasks that were previously deemed challenging. Many strategies use computer-based vision systems to extract plant traits and use them as input parameters for classifier systems. This research presents a unique classification model that incorporates neural networks (NN) to construct a computer-based vision system for automatically identifying plant species. This algorithm demonstrates the key steps, including data preprocessing, model training, evaluation, and deployment of a hybrid machine learning model for predicting plant diseases based on soil conditions.

Hybrid Machine Learning Model

Introduce the hybrid approach, combining supervised methods (e.g., Random Forest, Support Vector Machines) with unsupervised methods (e.g., clustering algorithms like K-Means). Explain the rationale behind the integration of both approaches for comprehensive disease prediction.

Hybrid Model Framework

Develop a hybrid framework integrating ensemble methods (Random Forest, Gradient Boosting), deep learning (neural networks), and statistical models. Determine the weighting mechanisms for each model in the ensemble to optimize predictive performance. A hybrid model framework typically refers to a combination of different modeling approaches or techniques to address a specific problem. In the context of machine learning or statistical modeling, a hybrid model often combines the strengths of different models to improve overall performance. Here, I'll provide a general overview and discuss a simple example of a hybrid model that combines linear regression and a neural network. Consider a regression problem: predict a target variable (Y) using input characteristics (X). The hybrid model combines a linear regression model and a neural network.

Linear Regression Model

The linear regression model predicts the target variable Y as a linear combination of input features X. The equation for a simple linear regression with one input feature is:

$$Y = b_0 + b_1 \cdot X$$

The intercept is denoted by b_0 , the coefficient for the input feature by b_1 , and the input feature itself by X.

Neural Network Model

The neural network is a complicated model made up of layers of linked nodes (neurons). Consider a basic neural network with a single hidden layer.

$$h = \sigma(W_1 \cdot X + b_1)$$

$$Y = W_2 \cdot h + b_2$$

Here, h is the hidden layer output, σ is the activation function, W_1 and b_1 are the hidden layer weights and biases, and W_2 and b_2 are the weights and biases of the output layer.





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Hybrid Model

The hybrid model combines both the linear regression and neural network predictions. Let Y_{linear} be the prediction from the linear regression model, and Y_{NN} be the prediction from the neural network. The final prediction Y_{hybrid} is a weighted combination:

$$Y_{\text{hybrid}} = \alpha \cdot Y_{\text{linear}} + (1 - \alpha) \cdot Y_{\text{NN}}$$

Here, α is a hyperparameter that determines the weight given to the linear regression model. Adjusting α allows you to control the influence of each model in the final prediction. The choice of combining models and the specific form of the hybrid model can vary based on the problem at hand. This is a simplified example, and in practice, hybrid models can involve more complex combinations of different model types.

Data Collection

Collect datasets encompassing soil properties (moisture, pH, nutrients), historical disease records, and meteorological data. Ensure data diversity across multiple crops, regions, and time periods.

Soil Data

Gather comprehensive soil data relevant to plant health. Include parameters such as pH, moisture levels, nutrient content (nitrogen, phosphorus, potassium), organic matter, etc.

Disease Labels

Collect labeled data indicating the presence or absence of plant diseases. This may involve visual inspections, lab tests, or data from previously diagnosed cases.

Data Preprocessing

Handle missing values, outliers, and normalize/standardize features. Explore dimensionality reduction techniques if necessary.

Experimental Setup

Training

Detail the training process for the hybrid model, including parameter tuning and validation techniques. Organize the dataset into training, validation, and testing sets. A common split may be 70% training, 15% validation, and 15% testing. Specify the metrics used to evaluate the model's performance.

Testing

Describe the testing phase and present the results of the hybrid model on unseen data.

RESULTS AND DISCUSSIONS

Provide insights into the accuracy and efficiency of the hybrid model compared to traditional methods. Discuss the significance of specific soil conditions in predicting plant diseases. Sure, let's consider a hypothetical scenario where you use a hybrid machine learning model to predict plant diseases based on soil conditions. Below is an example result table that you might use to analyze the performance of your model. Assume you have a test set with actual plant health statuses and corresponding predictions from your hybrid model.

Performance for Metrics

$$\text{Precision} = \frac{TP}{TP + FP}$$

$$\text{Recall} = \frac{TP}{TP + FN}$$

$$\text{Accuracy} = \frac{TP + TN}{TP + FN + TN + FP}$$





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$$F1 - Score = \frac{2 \times Precision \times Recall}{Precision + Recall}$$

1. The model accurately predicts plant health status in 87.5% of the samples.
2. With a precision of 85.7%, the model accurately predicts unhealthy plants 85.7% of the time.
3. Recall of 87.5% indicates that the model successfully detects 87.5% of the real sick samples.
4. The F1-score is a measure of precision and recall, and in this case it is 86.6%.

Challenges and Future Work

Address challenges encountered during the research, such as data limitations and model complexity. Propose potential avenues for future research, including the incorporation of real-time sensor data and the development of user-friendly interfaces for farmers.

CONCLUSIONS

In conclusion, utilizing hybrid machine learning methods to predict plant diseases based on soil conditions offers a promising approach that leverages the strengths of multiple models to enhance predictive accuracy and robustness. The use of many techniques, including Linear Regression, Support Vector Machine (SVM), and Neural Network, provides a comprehensive framework for handling complex relationships within the data. The use of hybrid machine learning methods holds great potential for advancing the accuracy and reliability of plant disease prediction on soil conditions. Through the combination of diverse algorithms, these models can contribute to more effective agricultural management, early disease detection, and informed decision-making for farmers and stakeholders.

REFERENCES

1. Elad, Y., & Pertot, I. (2014). Climate change impacts on plant pathogens and plant diseases. *Journal of Crop Improvement*, 28(1), 99-139.
2. Mohanty, S. P., Hughes, D. P., & Salathé, M. (2016). Using deep learning for image-based plant disease detection. *Frontiers in Plant Science*, 7, 1419.
3. Zarebanadkouki, M., Kim, Y. X., & Carminati, A. (2019). Where do roots take up water? Neutron radiography of water flow into the roots of transpiring plants growing in soil. *New Phytologist*, 224(3), 1049-1055.
4. Caruana, R., Niculescu-Mizil, A., Crew, G., & Ksikes, A. (2006). Ensemble selection from libraries of models. In *Proceedings of the 21st International Conference on Machine Learning (ICML-06)* (pp. 18).
5. Elad, Y., & Pertot, I. (2014). Climate change impacts on plant pathogens and plant diseases. *Journal of Crop Improvement*, 28(1), 99-139.
6. Mohanty, S. P., Hughes, D. P., & Salathé, M. (2016). Using deep learning for image-based plant disease detection. *Frontiers in Plant Science*, 7, 1419.
7. Zarebanadkouki, M., Kim, Y. X., & Carminati, A. (2019). Where do roots take up water? Neutron radiography of water flow into the roots of transpiring plants growing in soil. *New Phytologist*, 224(3), 1049-1055.

Table 1:

Sample	Actual Disease	Soil Condition Prediction	Plant Health Prediction	Hybrid Model Prediction
1	Healthy	Acidic	Healthy	Healthy
2	Diseased	Neutral	Diseased	Diseased
3	Healthy	Alkaline	Healthy	Healthy
4	Diseased	Acidic	Diseased	Diseased
5	Diseased	Neutral	Healthy	Diseased





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6	Healthy	Alkaline	Diseased	Healthy
7	Diseased	Acidic	Diseased	Diseased
8	Healthy	Neutral	Healthy	Healthy

Table:2

Metric	Value
Accuracy	87.50%
Precision	85.70%
Recall	87.50%
F1-Score	86.60%

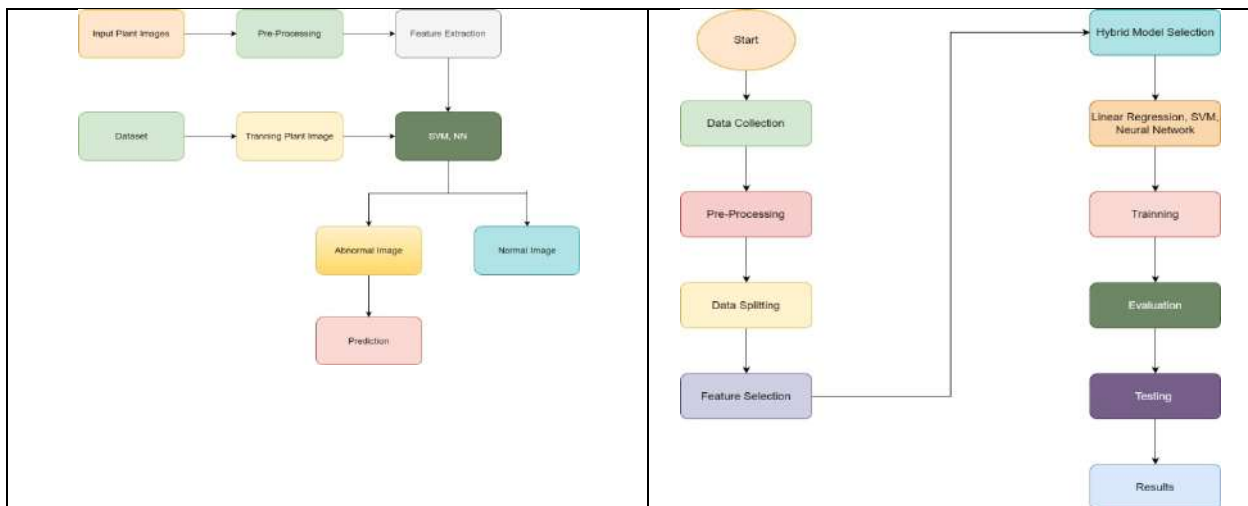


Figure 1: Proposal Model

Figure 2: Algorithm for Hybrid Machine Learning

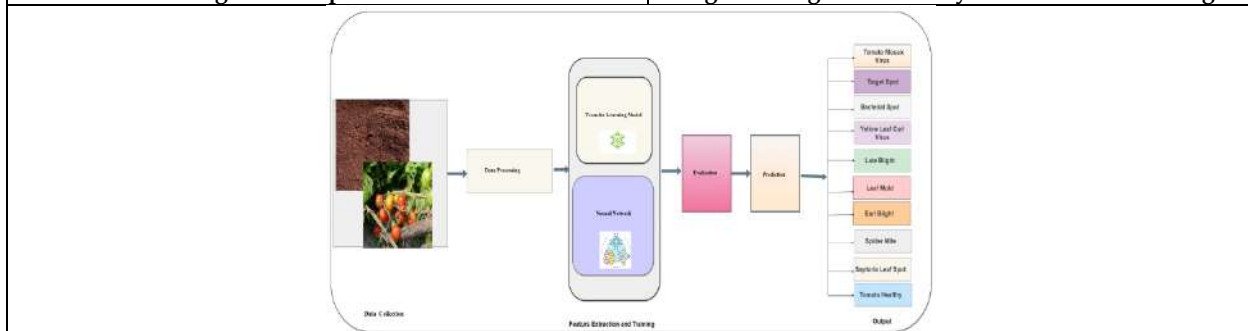


Figure 3





Phytochemical and Biological Investigation on Aerial Part of *Heliopsis helianthoides* Methanolic Extract

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ABSTRACT

Heliopsis helianthoides is a species of flowering plant in the family Asteraceae also known by the common names rough ox eye, smooth ox eye, and false sunflower, *Heliopsis helianthoids* is native to eastern and central North America from Saskatchewan east to Newfoundland and south as far as Texas, New Mexico, and Georgia Cultivated at Hill stations in India. *heliopsis helianthoides* rhizomatous herbaceous perennial growing plant claimed to be used traditionally in various ailments, the present study has attempted to evaluate the Aerial part of *Heliopsis helianthoides* for phytochemical screening by using Qualitative chemical tests & column chromatography. The study includes the biological evaluation of antimicrobial and antifungal activity. Phytochemical screening on the methanolic extract of the Aerial part of *Heliopsis helianthoides* shows the presence of Alkaloids, Steroidal glycosides, Tannins, and Saponins. In Biological Evaluation, Anti-Inflammatory, antibacterial and antifungal activities on extracts of *Heliopsis helianthoides* were tested. The Post hoc analysis showed remarkable Anti Inflammatory and Antibacterial activities and significant activity against the fungal organism.

Keywords: *Heliopsis helianthoides*, Methanolic Extract, Anti-Inflammatory Activity, Anti Microbial Activity, Anti-Oxidant Activity.





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INTRODUCTION

The part of pharmacognosy focusing on the use of crude extracts or semi-pure mixtures originating from nature, namely phytotherapy, is probably the best known and also the most debated area in pharmacognosy. Phytotherapy is sometimes considered alternative medicine ^[1], when critically conducted; it can be considered the scientific study of the effects and clinical use of herbal medicines. Consequently, herbal products might also become officially approved for clinical application as botanical drugs (e.g., Veregen (sinecatechins), a green tea leaves extract, approved for use by FDA). Most bioactive compounds of natural origin are secondary metabolites ^[2] i.e., species-specific chemical agents that can be grouped into various categories. A typical protocol to isolate a pure chemical agent from natural origin is bioassay-guided fractionation, meaning step-by-step separation of extracted components based on differences in their physicochemical properties, and assessing the biological activity, followed by the next round of separation and assaying. Typically, such work is initiated after a given crude drug formulation (typically prepared by solvent extraction of the natural material) is deemed "active" in a particular in vitro assay. If the end goal of the work at hand is to identify which one(s) of the scores or hundreds of compounds are responsible for the observed in vitro activity, the path to that end is fairly straightforward:

1. Fractionate the crude extract, e.g. by solvent partitioning or chromatography.
2. Test the fractions thereby generated with in vitro assay.
3. Repeat steps 1) and 2) until pure, active compounds are obtained.
4. Determine structure(s) of active compound(s), typically by using spectroscopic methods.

PLANT DESCRIPTION OF *HELIOPSIS HELANTHOIDES*

Distribution and Habitat

Heliopsis helianthoides ^[3] is a species of flowering plant in the family Asteraceae; known by the common names rough oxeye, smooth oxeye, and false sunflower. *Heliopsis helianthoides* (Fig 1) is a rhizomatous herbaceous perennial growing 40-150 cm (16-59 in) tall. The toothed leaf blades are oval to triangular or lance-shaped and may be smooth or hairy or rough in texture. The flowers are produced from midsummer to early autumn (fall). The inflorescence contains one to many composite flower heads. Each head contains yellow ray florets which are generally 2-4 cm (3/4-1 1/2 in) long. At the center are many yellow to brownish disc florets.

Taxonomical Classification

- ❖ Kingdom: Plantae
- ❖ Division: Tracheophytes
- ❖ Clade: Angiosperms
- ❖ Order: Asterales
- ❖ Family: Asteraceae
- ❖ Genus: Heliopsis
- ❖ Species: H.helianthoides

Botanical Description

Heliopsis helianthoides is a rhizomatous herbaceous perennial growing 40-150 cm (16-59 in) tall. The toothed leaf blades are oval to triangular or lance-shaped and may be smooth or hairy or rough in texture. The flowers are produced from midsummer to early autumn (fall). The inflorescence contains one too many composite flower heads. Each head contains yellow ray florets which are generally 2-4 cm (3/4-1 1/2 in) long. At the center are many yellow to brownish disc florets. ^[4]





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Medicinal Uses

The sweet ox-eye has a few medicinal and edible uses. The flowers of the plant are edible and can be used in a salad or as a garnish. The plant can be used in medicinal drinks, primarily for the treatment of lung troubles. The leaves can be made into a strong tea that can reduce fevers and loosen phlegm. The stems can be used to treat malaria.^[5]

MATERIALS AND METHODS

Plant collection and Identification

The Specimen of the Aerial part of the plant was collected from *Heliopsis helianthoides* plant in Hill areas of Araku, Visakhapatnam, and Andhra Pradesh.

Preparation of Crude Extract

500 grams of the dried coarsely powdered crude drug is subjected to Soxhlet extraction with a sufficient volume of Methanol.^[6] The extraction process is continued for 3-4 cycles until extraction is completed, filtered, and then subjected to distillation to concentrate crude extract. The crude extract is then transferred to a china dish and was dried in desiccators for over a week.

Phytochemical Screening^[7,8] of Crude Extract of *Heliopsis helianthoides*

1 Gram of sample is subjected to Phytochemical screening by performing chemical tests, the crude extract showed the presence of Alkaloids, Steroidal glycosides, Tannins, and Saponins. (Table: 1)

BIOLOGICAL SCREENING

ANTI INFLAMMATORY ACTIVITY

The methanol extracts on aerial parts of *Heliopsis helianthoides* were screened for Anti-inflammatory activity^[9] by Inhibition of albumin denaturation Method. Protein denaturation^[10] is when proteins lose their tertiary structure and secondary structure by applying external stress or compound, such as strong acid or base, a concentrated inorganic salt, an organic solvent, or heat. Most biological proteins lose their biological function when denatured. Denaturation of proteins is a well-documented cause of inflammation. The following procedure was followed for evaluating the percentage of inhibition of protein denaturation.

Preparation of Solutions.^[11]

Control solution (25ml): In a test tube add 1 ml egg albumin, 14ml phosphate buffer of pH 7.4 and 10ml distilled water.

Standard solution (25ml): Five test tubes are taken and to each test tube add 10ml of diluted standard solution of aspirin, 1ml egg albumin and 14ml phosphate buffer of pH 7.4 to give varying concentrations (200-1000µg/ml) of standard solution with volume 25ml.

Test solution (25ml): Five test tubes are taken and to each test tube add 1ml egg albumin, 14ml phosphate buffer of pH 7.4 and 10ml of diluted extract solution to get varying concentrations (200-1000µg/ml) of test solution. (Table: 2)

All the mixtures were incubated at (37±2) °C in a BOD incubator for 30 minutes and heated at 70°C for 15 minutes. After cooling, the absorbance was measured at 660 nm by using UV- visible spectrophotometer. Percentage inhibition of protein denaturation was calculated using the formula,

$$\text{Percentage of inhibition} = \left[\frac{\text{VT}}{\text{VC}} - 1 \right] \times 100$$

Where, VT = Absorbance of test sample

VC = Absorbance of control

The results obtained were summarized in table-1. The present findings suggest that inhibition of denaturation of protein by *Heliopsis helianthoides* plant extract is concentration dependent in the range of (200-1000µg/ml). The concentrations of aspirin used in the experiments were same as that of *Heliopsis helianthoides* plant extract. (Table:3) and (Graph:1)





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ANTI-BACTERIAL ACTIVITY

The methanol extracts on arial parts of *Heliopsis helianthoids* were screened for antibacterial activity [12] against two Gram-positive bacteria viz., *Staphylococcus aureus*, and two Gram-negative bacteria viz., *Escherichia coli* by using the cup plate method. Amikacin was used as a reference standard for comparing the results [13]. The nutrient broth was used for the preparation of the inoculums of the bacteria and nutrient agar was used for the screening method.

Methanol extract of *Heliopsis helianthoids* (5 mg) was dissolved in 5 ml methanol, to give a concentration of 1000µg/ml. Amikacin solution was also prepared to give a concentration of 1000 µg/ml in sterilized distilled water. The Extract was tested at dose levels of 12.5µg, 25µg, and 50µg, and methanol was used as a control. The solutions of extract of different concentrations mentioned above, control and reference standard (20µg) were added separately in the cups and the plates were kept undisturbed for at least 2 hrs in a refrigerator to allow diffusion of the solution properly into nutrient agar medium. Petri dishes were subsequently incubated at 37 ± 10C for 24 hrs. After incubation, the diameter of the zone of inhibition surrounding each of the cups was measured with the help of an antibiotic zone reader. All the experiments were carried out in duplicate. [14] (Table: 4) (Graph: 2)

ANTIOXIDANT ACTIVITY

DPPH method for free radical scavenging activity:

Crude extract of *Heliopsis helanthoides* was subjected to antioxidant activity [15] by using the following method.

- DPPH (1, 1-diphenyl-2-picryl hydrazyl) radical scavenging Method

The method is based on the reduction of the colored solution of DPPH (1,1-diphenyl-2-picryl hydrazyl) in the presence of a test drug measured at 516 nm. The activity is expressed as IC₅₀, which is the concentration of the test solution required to give a 50% decrease in absorbance compared to the blank solution. [16]

Reagents:

1. DPPH solution: 0.004% DPPH in ethanol was prepared (4mg of DPPH in 100ml of Methanol) and kept overnight in a dark place for the generation of free radicals.
2. Test solutions: 1 mg/ ml test solutions of all the fractions of *Heliopsis helanthoides* were prepared in Methanol

PROCEDURE

To the methanolic solution of DPPH (0.004%), 0.1mL of various concentrations of the test fractions dissolved in Methanol were added. An equal amount of Methanol was added to the control. Ascorbic acid was used as standard. After 15 minutes, the decrease in the absorbance of test fractions (due to quenching of DPPH free radicals) [17] was read at 516 nm. A linear graph of concentration versus percentage inhibition was prepared and IC₅₀ values were calculated. (Table: 5, 6) (Graph: 3) The percentage inhibition was calculated according to the following equation:

$$\% \text{inhibition} = (A_0 - A_t) / A_0 \times 100$$

Where

A₀ was the absorbance of the control (blank without extract) and

A_t was the absorbance in the presence of the extract.

DISCUSSIONS

The works are done on the Arial part of *Heliopsis helianthoids* by emphasizing extraction, phytochemical screening, separation of constituents, and biological activities. The crude extract is screened for phytochemical constituents that showed the presence of **Alkaloids, Tannins, Saponins, and Steroidal triterpenes**. The separation of compounds was done by performing column chromatography. We also noted that the extraction of *Heliopsis helanthoides* showed effective in inhibiting heat-induced albumin denaturation. Maximum inhibition of 90.5% was observed at 1000µg/ml for methanolic plant extract and aspirin, a standard anti-inflammation drug showed the maximum inhibition of 99.28% at the concentration of 1000µg/ml compared with control, significant Antimicrobial activity by comparing the concentrations of 12.5µg/ml, 25µg/ml, and 50µg/ml of crude methanolic sample with that of the standard concentration, the concentration of 50 µg/ml showed the moderate activity. Extract of *Heliopsis helanthoides* was performed for Antioxidant activity by the DPPH method with different concentrations. DPPH method showed significant antioxidant activity than the standard at 300µg/ml concentration





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CONCLUSIONS

The extract is detected for chemical constituents, screened for Anti-Inflammatory, Antimicrobial Antioxidant activities. Finally, we concluded that the crude extract of *Heliopsis helianthoides* showed optimum Anti-Inflammatory, Significant anti microbial and antioxidant activities. Further work can be done for the isolation and separation of individual chemical compounds and Biological evaluation of several activities.

REFERENCES

1. J Raghunathan K, Mitra R. Pharmacognosy of Indigenous Drugs. Vol. I, Government of India: Central council for Research in Ayurveda and siddha, 2000, 158-183.
2. Kirthikar KR, Basu BD. Indian Medicinal Plants, 2nd Ed, Vol. II, India: Popular Publications Dehradun, 1999, 1224-1227.
3. *Heliopsis helianthoides*. USDA NRCS Plant Guide
4. Smith, Alan R. (2006). "Heliopsis helianthoides". In *Flora of North America Editorial Committee (ed.). Flora of North America North of Mexico (FNA)*. Vol. 21. New York and Oxford – via eFloras.org, Missouri Botanical Garden, St. Louis, MO & Harvard University Herbaria, Cambridge, MA.
5. Zlesak, D. C. "Factors affecting seed germination of *Heliopsis helianthoides* (L.) Sweet." *Seed Science and Technology* 35.3 (2007): 577-594.
6. Jakupovic, J.; Schuster, A.; Chau-Thi, T.V.; Bohlmann, F.; Dominguez, X.A. Guaianolides and homoditerpenes from *Heliopsis helianthoides*. *Phytochemistry* **1988**, 27, 2235–2240.
7. Hajdu, Z.; Nicolussi, S.; Rau, M.; Lorántfy, L.; Forgo, P.; Hohmann, J.; Csupor, D.; Gertsch, J. Identification of endocannabinoid system-modulating N-alkylamides from *Heliopsis helianthoides* var. *scabra* and *Lepidium meyenii*. *J. Nat. Prod.* **2014**, 77, 1663–1669
8. Aguilar MI, Castillo N, Aguilar-Guadarrama AB, Rios MY. Quality specifications of identity and composition for the medicinal plant *Heliopsis longipes*. *Planta Med.* 2008; 74:PC98.
9. Rajkumara S, Pandiselvi A, Sandhiya. Isolation of Chemical Constituents from *Mimusops elengi* bark and Evaluation of Anti-inflammatory activity. *Int J Phytopharmacy* 2012; 3(1):9-15
10. Gunathilake, K; Ranaweera, K; Rupasinghe, H. (2018). In Vitro Anti-Inflammatory Properties of Selected Green Leafy Vegetables. *Biomed.* 6(4):107.
11. Kar B, Kumar RB, Karmakar I, Dolai N, Bala A, Mazumder UK, et al. Antioxydant and in in-vitro anti-inflammatory activities of *Mimusops elengi* leaves. *Asian Pacific Journal of Tropical Biomedicine* 2012; 2(2):976-980
12. De Boer HJ, Kool A, Broberg A, Mziray WR, Hedberg I, Levenfors JJ. Antifungal and antibacterial activity of some herbal remedies from Tanzania. *J Ethnopharmacol*, 2005; 96: 461-469.
13. Tadhani BM, Subash R. In Vitro Antimicrobial Activity of *Stevia Rebaudiana* Bertoni Leaves. *Trop J Pharm Res*, 2006; 5 (1): 557-560.
14. Prabhat, Ajaybhan, Navneet, Chauhan A. Evaluation of Antimicrobial Activity of Six Medicinal Plants against Dental Pathogens. *Report Opinion* 2010; 2(6):37-42.
15. Skrovankova S, Misurcova L, Machů L. (2012). Antioxidant activity and Health effects of common medicinal plants. *Adv Food Nutr Res.* 67:75-139
16. Islam RT, Islam AT, Mazumder K. In vitro antioxidant activity of methanolic extract of *Helianthus annuus* seeds. *J Med Plants Stud.* 2016; 4(2):15-7
17. Tarko, T.; Duda-Chodak, A.; Soszka, A. Changes in phenolic compounds and antioxidant activity of fruit musts and fruit wines during simulated digestion. *Molecules* **2020**, 25, 5574.





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Table 1: Results of Phytochemical screening on *Heliopsis helanthoides* Extract

S.No	Secondary metabolites	Results in <i>Heliopsis helanthoides</i> Extract
1	Alkaloids	Positive
2	Steroidal glycosides	Positive
3	Saponins	Positive
4	Carbohydrates	Negative
5	Flavanoids	Negative
6	Tannins	Positive
7	Glycosides	Negative

Anti-Inflammatory Activity**Table: 2 Preparation of Sample and Test solutions**

Concentration ($\mu\text{g/ml}$) of test and standard solution	Volume of reference standard solution and sample solution (ml)	Volume of distilled water (ml)
200 $\mu\text{g/ml}$	2	8
400 $\mu\text{g/ml}$	4	6
600 $\mu\text{g/ml}$	6	4
800 $\mu\text{g/ml}$	8	2
1000 $\mu\text{g/ml}$	10	0

Table-3: Results of effect of aspirin and *Heliopsis helianthoides* plant extract on protein inhibition

S.No	Concentration ($\mu\text{g/ml}$)	Effect of aspirin on protein denaturation (% inhibition)	Effect of methanolic plant extract on protein denaturation (% inhibition)
1	200 $\mu\text{g/ml}$	19.7828	10.8564
2	400 $\mu\text{g/ml}$	49.5428	29.5536
3	600 $\mu\text{g/ml}$	70.1507	48.3437
4	800 $\mu\text{g/ml}$	88.2328	70.1809
5	1000 $\mu\text{g/ml}$	99.2846	90.4981

Anti-Microbial Activity:**Table: 4 Results for the anti microbial activity:-**

Concentration in $\mu\text{g/ml}$	Zone of Inhibition on <i>Staphylococcus aureus</i> in mm	Zone of Inhibition on <i>Escherichia coli</i> in mm
Standard (Rifampicin)	13 mm	12 mm
Control (methanol)	2 mm	4 mm
12.5 $\mu\text{g/ml}$	7 mm	9 mm
25 $\mu\text{g/ml}$	8 mm	8 mm
50 $\mu\text{g/ml}$	10mm	7mm





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Anti-Oxidant Activity:**Table:5 % inhibition of *Heliopsis helanthis* extract by DPPH method:-**

Concentration	Absorbance	% Inhibition
0 µg/ml	0.694	
50 µg/ml	0.586	15.56
100 µg/ml	0.522	24.78
150 µg/ml	0.483	30.40
200 µg/ml	0.419	39.63
250 µg/ml	0.351	49.42
300 µg/ml	0.225	67.58

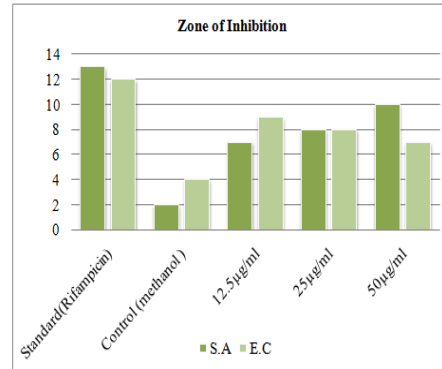
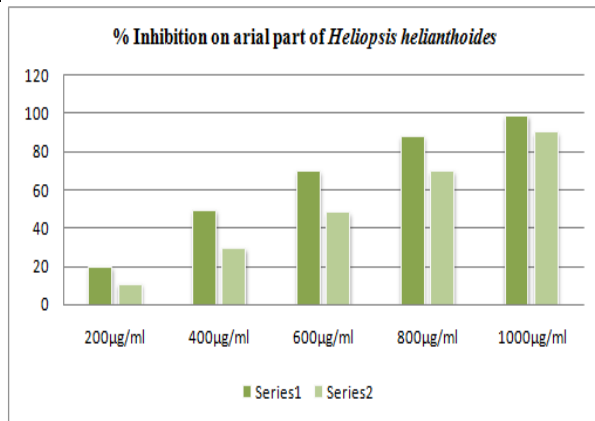
Table: 6 % inhibition of Standard Drug by DPPH method:-

Concentration	Absorbance	% Inhibition
Control	0.149	
50 µg/ml	0.132	11.4094
100 µg/ml	0.113	24.16107
150 µg/ml	0.095	36.24161
200 µg/ml	0.084	43.62416
250 µg/ml	0.076	48.99329
300 µg/ml	0.069	53.69128





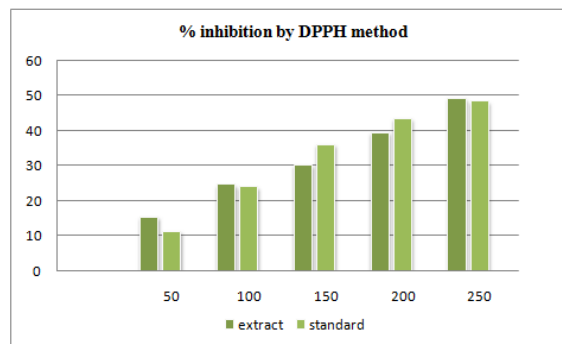
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Graph:1 Anti-Inflammatory Activity on arial part of *Heliopsis helianthoides*

Series 1 – effect of aspirin on protein denaturation (%inhibition) **Series 2** – effect of methanolic plant extract on protein denaturation(%inhibition)

Graph: 2 Zone of Inhibition



GRAPH: 3 % inhibition by DPPH method:-





Exogenous Application of Brassinolide and Alpha-Tocopherol Improving Physiological, Biochemical, and Harvest Attributes in *Vigna radiata* L. (Co-6) variety Under Salinity Stress

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ABSTRACT

Excessive soil salinity, raised from high salt concentrations, is a harsh environmental factor that severely affects the sensitivity of most crop plants to these conditions hampers their productivity, placing constraints on their growth and development. The primary limitation to crop production globally persists in the form of abiotic stresses. To counteract the negative impact of NaCl stress on crops, alternative methods like using plant growth regulators and vitamins can help mitigate these effects. In this perspective, the current investigation was carried out to examine the impact of externally applied Alpha-tocopherol and Brassinolide (BL) on physiological, biochemical, and yield traits of *Vigna radiata* L. (Co-6) variety under NaCl stress in pot culture. Physiological and biochemical parameters were assessed by randomly collecting fresh plant leaves from each treatment on the 25th, 35th, and 45th days after sowing (DAS). Seed harvest was conducted when the seeds reached maturity. Salt stress leads to a reduction in both relative water content and membrane stability index, accompanied by a significant increase in ion leakage, as well as the accumulation of proline and glycine betaine. Similarly, NaCl stress results in a significant reduction in grain yield. However, foliar Application of Alpha-toc and BL increased membrane stability index (MSI) and relative water content (RWC). This led to a reduction in electrolyte leakage (EL), and proline, aiding the plant in recovering from NaCl-induced stress. As a result, the plants showed improved tolerance to salt stress, contributing to enhanced yield and related characteristics.

Keywords: salinity, stress, Alpha-tocopherol, brassinolide, NaCl, crop plants.



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INTRODUCTION

Salinization of soil, a threat to the soil fertility, is increasing steadily in different parts of the world, especially in arid, semiarid, and areas which are heavily irrigated by salt-containing water. Soils with an electrical conductivity of the saturation extract (EC_c) at 4 dS m⁻¹ or higher are considered saline, and those with EC_c exceeding 15 dS m⁻¹ are classified as strongly saline. [1]. High salt levels in the soil create osmotic stress, making it difficult for plants to absorb water and nutrients. This imbalance disrupts the plant's internal stability, resembling a drought-like condition, ultimately impacting their growth and overall growth and development.[2,3].An imbalance of Na⁺ and Cl⁻ causes osmotic stress in plants, reducing their cellular osmotic potential and triggering the accumulation of solutes like proline, mannitol, sorbitol, and glycine betaine. This stress also leads to ROS production, causing oxidative stress and potential cellular damage. [4]The adverse impact of ROS stems from their ability to initiate autoxidative reactions on unsaturated fatty acids and cause lesions in plant DNA, leading to deletions, mutations, and other genetic damage, which can be lethal and reduce plant growth productivity. [5]. During stress, plants accumulate osmolytes to alleviate osmotic pressure without disrupting metabolism. These solutes maintain cell turgor for water uptake and may also scavenge free radicals or act as chemical chaperones, stabilizing membranes and proteins.

[6,7].Therefore, improving plant's ability to withstand salt stress is crucial for sustainable farming. Understanding how they adapt to changing soil salinity helps create resilient crops through genetics or breeding. Leveraging these natural processes and advanced tech leads to salt-tolerant crops, securing food in tough conditions. [8]. Enduring salinity stress requires a multifaceted approach, not just a single strategy. Foliar application of alpha-tocopherol (α-tocopherol) is one method to enhance plant development under salinity stress, as it functions as an antioxidant, reducing cellular oxidation. [9]Alpha-tocopherol helps plants in saline conditions by countering harmful oxygen species, protecting membranes, and boosting chlorophyll and carotenoid levels.[10,11]. Moreover, spraying of Alpha-tocopherol has been found to increase enzymatic anti-oxidants, crop yield, and productivity as found in *Vigna radiata* L. [12]. Brassinolide is identified as a biologically active BR compound, assumes a critical role in developmental mechanisms, and notably fortifies plant resilience against a spectrum of abiotic stress factors. [13]Brassinolide boosts plant defenses by enhancing chlorophyll, photosynthesis, antioxidants, and stress-responsive enzymes like SOD, POD, CAT, GR, and APX.[14].Foliar treatments administered in conventional circumstances also augment plant growth and the net photosynthetic rate, thereby demonstrating their multifaceted functionalities. [15]*Vigna radiata* L. is a significant food grain legume, with high economic importance. It serves as an excellent dietary protein source, boasting substantial nutritional benefits, particularly beneficial for individuals adhering to a vegetarian diet.[16]. However, it shows less resistance to salt stress. Since its yield is greatly affected by saline conditions. In this study, we studied foliar-applied Alpha-toc and Brassinolide to check their impact on physiological, compatible solutes and yield characteristics aiming to improve salt tolerance, enhance crop growth, and increase yields.

MATERIAL AND METHODS

Seed collection and Growth regulators

The *Vigna radiata* L. (Co-6) variety seeds were collected from Tamil Nadu Agricultural University Coimbatore India. The growth regulators Alpha-tocopherol and Brassinolide, and analytical reagent grade NaCl as well were purchased from HI-Media company, Mumbai Ltd.

Experimental design

The seeds chosen for the study were planted in plastic pots containing a uniform mixture weighing 10 kg, comprised of red soil, sand, and farmyard manure in a 1:1:1 ratio for sowing purposes. On the 15th day after sowing (DAS), salt stress was induced gradually by administering NaCl salt treatment at a concentration of 500ml L⁻¹. This incremental approach was adopted to achieve the target concentration of 80mM while mitigating sudden salt shock to the plants.Following this, the necessary salt concentration was maintained by monitoring the soil electrical conductivity



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(EC) until the completion of the experiment. The plants were treated in Control, NaCl (80Mm), (Alpha-Toc + NaCl), (BL + NaCl), Alpha-Toc(200mg/L), and BL (4mg/L), and they were sprayed on both sides of leaves and stem. the plants were harvested for physiological and biochemical parameters for analysis on the 25th, 35th, and 45th DAS respectively.

Relative leaf water content (RLWC)

The relative water content (RWC) was determined in fresh leaf discs of 2Cm² diameter, excluding midrib. Discs were weighed quickly and immediately floated on deionized distilled water (DDW) in Petri dishes to saturate them with water for the next 4h, in the dark. The adhering water of the discs was blotted and turgor mass was noted. The dry mass of the discs was recorded after dehydrating them at 80°C for 24 h in a hot air oven. RWC was calculated according to the formula. (Barrs H, & Weatherley 1962)

$$\text{RWC (\%)} = [\text{FW} - \text{DW}] / [\text{TW} - \text{DW}] \times 100$$

Membrane stability index (MSI).

The membrane stability index (MSI) was calculated by combining 100 mg of leaf tissue with 10 ml of DDW in two independent sets. One set was heated in a water bath at 40°C for 30 minutes, and the electrical conductivity bridge C₁ was measured using a conductivity meter (LABTRONICS-Model LT-23). The second set was heated in a water bath at 100°C. The electrical conductivity C₂ was also measured using a conductivity meter after 10 minutes. MSI was determined using the formula. (Sairam 1994).

$$\text{MSI} = [1 - (\text{C}_1/\text{C}_2)] \times 100$$

Electrolyte leakage determination (EL)

(Sullivan, & Ross 1979) method used to estimate the total inorganic ions lost out of the leaves .20 leaf discs were placed in a boiling test tube of 10 ml deionized water and their electrical conductivity (EC_a) was measured. The content was heated in a water bath at 45°C and 55°C for 30 minutes each, and electrical conductivity (EC_b) was measured. The content was subsequently heated up again for 10 minutes at 100 °C and the electrical conductivity (EC_c) was measured. The electrolyte leakage has been calculated by following the formula:

$$\text{Electrolyte leakage (\%)} = \frac{\text{EC}_b - \text{EC}_a}{\text{EC}_c} \times 100.$$

Yield and yield traits.

For the determination of grain yield and other related characters fully matured pods were harvested from each plant separately. Afterwards, pod length, pod number, and number of seeds per pod were determined and recorded. Subsequently, the seeds were separated from each pod and dried in order to quantify the 100-seed weight and yield per plant.

Proline content

Proline content in fresh plant materials was analyzed using the Bates *et al.* method(1973). Fresh leaf materials (50 mg) were cryogenically ground in liquid nitrogen, mixed with 1 mL of 3% w/v aqueous sulfosalicylic acid, and filtered through Whatman filter paper. The solution was then combined with Glacial acetic acid and ninhydrin reagent (1.25 mg Ninhydrin in 30 mL of Glacial acetic acid and 20 mL of 6 M H₃PO₄) and reacted at 95°C for an hour, stopped in an ice bath. Toluene (2 mL) was added, and the chromophore was detected at 520 nm after warming to 25 °C, with L-proline as the calibration standard.

Statistical Analysis

One-way ANOVA was used after statistical analysis of the data using SPSS software (version 22.0). The data collected, shown in bars, consist of the standard error (SE) and mean values of three replicates (n = 3). Duncan's Multiple Range Test was used to determine the significance level of 0.05 percent (DMRT).





RESULTS AND DISCUSSION

Leaf relative water content (LRWC)

The NaCl stress given at 80mM level significantly declined relative water content (RWC) in the leaves of green gram plants displayed in (Figure 1). The plants treated with NaCl + Alpha-Toc and NaCl + BL showed a slight reduction than the control plants., However, the plants treated with Alpha-tocopherol and brassinolide show increased (RWC) than the control. A decline in relative water content was observed with rising salinity levels in *Oryza sativa* L. [17]. Comparable findings were also documented in wheat, *Triticum aestivum* L. [18], and pepper *Capsicum annuum* L. [19].Brassinolide plays a pivotal role in modulating a range of physiological functions and bolstering plant resilience to abiotic stresses in *Malus hupehensis* [20] as well as in strawberry cultivars. [21] Foliar application of significantly the water tolerance and ameliorate the salinity stress effect in wheat [22] and *Solanum melongena* L. [23].

Membrane stability index (MSI)

Salt stress decreases the membrane stability index, the plants treated with NaCl show reduction in the MSI as compared to the control plants. (Fig-2). However, the plants treated with Alpha-Toc and BL show enhanced membrane stability index compared to control.The NaCl + Alpha-Toc and BL + NaCl treated plants show reduced MSI than the NaCl treatment plants alone. Amidst salt stress, the Membrane Stability Index (MSI) exhibited a decline across all examined pea varieties, suggesting an escalation in membrane impairment as salinity levels increased these underscores the significance of MSI as a valuable tool for assessing salt tolerance in these genotypes. Higher MSI levels may signify better resilience to salt stress, assisting in the identification of more strong pea varieties [24].The plants treated with α -tocopherol (α TOC) displayed enhancements in performance index, relative water content, membrane stability index, and nutrient status, all of which showed inter-connections in the Alpha-toc treated plants. [25]. However, the exogenous application of BL improved membrane integrity to different extents as found in *Lycopersicon esculentum* [26] and *Zea mays* [27].

Electrolyte leakage determination (EL)

Electrolytic leakage increases in the plants treated with NaCl, compared to control. (Fig-3) however, the plants treated with Alpha-tocopherol and Brassinolide show less EL leakage concentration. And the plants treated with NaCl + Alpha-Toc and BL + NaCl showed comparatively higher EL values than the control. Electrolyte leakage serves as an indicator of membrane damage, especially in the plasma membranes, which bear the brunt of salt-induced injury caused by specific ions. [28]. As a result, detecting electrolyte leakage from plasma membranes is a vital marker for recognizing salt-tolerant canola plants (*Brassica napus* L.). [29] The brassinolide has a prominent role in declining the electrolytic leakage as in pepper plants [30].The incorporation of Alpha-Toc effectively alleviated the detrimental effects of salt stress, leading to a decrease in electrolyte leakage (EL) values and consequent mitigation of membrane damage in barley and rapeseed. [31].

Yield and Yield attributes

Salinity has Adverse effects on the yield attributes declining the yield of the plants.[32]. According to this study, the plants under salt stress show a higher reduction in yield attributes (such as pod length, No. of seeds/pod, No. of pods/plant, 100-seeds weight, and yield/plant) than Control plants. however, the plants treated with Alpha-Toc and Brassinolide mitigated the adverse effects of salinity and enhanced the growth attributes compared to control,and the plants treated with NaCl + Alpha-Toc and BL + NaCl showed better yield than the plants treated with NaCl alone. (Fig-4). High salinity stress led to decreased grain weight and fewer spikelets per panicle in rice (*Oryza sativa* L.), contributing to lower harvest index and grain yield.[33]. Foliar application of α -Toc markedly elevated wheat plants' resilience to water stress, showcasing remarkable improvements in their growth and eventual yield attributes. [34].BL application in crops has shown a significant protective effect against salt stress, mitigating potential biomass and yield losses in cucumber (*Cucumis sativus* L.)[35].



**Aamir Abdullah et al.,****PROLINE CONTENT**

Proline functions in safeguarding plant cells during osmotic stress by serving as a compatible solute. Additionally, it acts as both an antioxidant and a scavenger of reactive oxygen species (ROS) due to its role as a molecular chaperone [36].

Leaf

Proline is the primary naturally occurring osmolyte accumulated in plants under different abiotic stresses, including salinity. [37]. According to our experimental investigation, salt-induced stress in *Vigna radiata* L. resulted in elevated levels of proline content in the plant leaves on different sampling days. The percentages recorded were 222.5%, 214.4%, and 202.5% higher compared to the control on the 25th, 35th, and 45th, DAS respectively. (Fig-5) the plants treated with NaCl + Alpha-Toc and NaCl + BL had lower proline content it was found 151.1% and 187.5% than NaCl-treated plants, on 45th DAS. However, the plants treated with Alpha-toc and BL had less proline content than all salt-treated plants but higher than control and it was found 136.7% and 139.8% DAS respectively. The proline content within the leaves of *Portulaca oleracea* L. exhibited a rising trend alongside escalating salinity levels. [38], *Spinacia oleracea* L. [39], Applying BL and Alpha-tocopherol externally alleviates the impact of salt stress by promoting increased accumulation of proline in *Brassica juncea* L. and Okra sps. [40,41]

Stem

Proline content in plant stems of salt-stressed treated *Vigna radiata* L. on sampling days and it was recorded at 336.2%, 264.0%, and 168.9% over control on 25th, 35th, and 45th DAS respectively. (Fig-6) In the plants treated with Alpha-toc and BL the percentage of proline content found was 103.4%, 113.7% higher than the control. However, in the plants treated with NaCl + Alpha-toc and NaCl + BL, the content of proline found was 125.5%, and 155.1% than control. It has been found salinity increases proline concentration in *soybean*, and *Portulaca oleracea* L. [42,43].

Root

According to this study, the proline concentration found in the roots of NaCl-treated plants of *Vigna radiata* L. is 227.36%, 150.75%, and 147.82% over control on 25th, 35th, 45th, DAS respectively. (Fig-7) However, the application of Alpha-toc and BL to salt-stressed plants showed less proline concentration than the NaCl-treated plants and it was 119.13% and 131.59% over control on 45th DAS respectively. The plants treated with Alpha-toc and BL without salt stress showed 111.30%, and 101.4% over control on 45th DAS respectively. Under conditions of salt stress, the accumulation of proline has been identified as positively associated with salt tolerance. Proline may play a crucial role in enhancing salinity tolerance in certain plant species. [44]. The use of external Brassinolide (BL) has been noted to alleviate salt stress in *Solanum tuberosum* (potato) and *Vigna radiata* L. (mung bean) by stimulating enhanced production of proline. [45,46]. Foliar spray of alpha-tocopherol improved salt stress tolerance in wheat (*Triticum Aestivum* L.). [47].

CONCLUSION

Salinity is the main factor restricting plant growth and productivity due to excessive salts in the soil, affecting various physiological, and biochemical processes, etc. The findings revealed that applying Alpha-tocopherol and brassinolide to green gram (Co-6) variety plants effectively regulates physiological and biochemical changes, such as RWC, Membrane stability index, yield, proline, and Glycine betaine. This control minimizes the negative impact of salinity by reducing ROS-induced electrolyte leakage (EL), crucial for enhancing NaCl stress tolerance and maintaining plant yield. It can be concluded that the application of Alpha-tocopherol and Brassinolide externally can boost the salt stress resilience in green gram plants grown under saline conditions.

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REFERENCES

1. Giri, B., Kapoor, R., & Mukerji, K. G. (2007). Improved tolerance of *Acacia nilotica* to salt stress by arbuscular mycorrhiza, *Glomus fasciculatum* may be partly related to elevated K/Na ratios in root and shoot tissues. *Microbial ecology*, 54, 753-760.
2. Porcel, R., Aroca, R., Azcon, R., & Ruiz-Lozano, J. M. (2016). Regulation of cation transporter genes by the arbuscular mycorrhizal symbiosis in rice plants subjected to salinity suggests improved salt tolerance due to reduced Na⁺ root-to-shoot distribution. *Mycorrhiza*, 26, 673-684.
3. Zhu, J. K. (2001). Cell signaling under salt, water and cold stresses. *Current opinion in plant biology*, 4(5), 401-406.
4. Rasool, S., Hameed, A., Azooz, M. M., Siddiqi, T. O., & Ahmad, P. (2013). Salt stress: causes, types, and responses of plants. *Ecophysiology and responses of plants under salt stress*, 1-24.
5. Tuteja, N., Ahmad, P., Panda, B. B., & Tuteja, R. (2009). Genotoxic stress in plants: shedding light on DNA damage, repair and DNA repair helicases. *Mutation Research/Reviews in Mutation Research*, 681(2-3), 134-149.
6. Ahmad, P., & Prasad, M. N. V. (Eds.). (2011). *Environmental adaptations and stress tolerance of plants in the era of climate change*. Springer Science & Business Media.
7. Ahmad, P., & Prasad, M. N. V. (Eds.). (2011). *Abiotic stress responses in plants: metabolism, productivity and sustainability*. Springer Science & Business Media.
8. Kamanga, R. M., Echigo, K., Yodoya, K., Mekawy, A. M. M., and Ueda, A. (2020). Salinity acclimation ameliorates salt stress in tomato (*Solanum lycopersicum* L.) seedlings by triggering a cascade of physiological processes in the leaves. *Sci. Hortic.* 270, 109434.
9. Mahmood, A., Bibi, S., Naqve, M., Javaid, M. M., Zia, M. A., Jabbar, A., ... & Fiaz, S. (2022). Physiological, Biochemical, and yield responses of linseed (*Linum usitatissimum* L.) in α -Tocopherol-mediated alleviation of salinity stress. *Frontiers in Plant Science*, 13, 867172.
10. Zandi, P., & Schnug, E. (2022). Reactive oxygen species, antioxidant responses and implications from a microbial modulation perspective. *Biology*, 11(2), 155.
11. Hajjhashemi, S., Brestic, M., Landi, M., & Skalicky, M. (2020). Resistance of *Fritillaria imperialis* to freezing stress through gene expression, osmotic adjustment and antioxidants. *Scientific reports*, 10(1), 10427.
12. Sadiq, m. u. h. a. m. m. a. d., Akram, N. A., & Javed, M. T. (2016). Alpha-tocopherol alters endogenous oxidative defense system in mung bean plants under water-deficit conditions. *Pak. J. Bot*, 48(6), 2177-2182.
13. Yuan, L., Shu, S., Sun, J., Guo, S., & Tezuka, T. (2012). Effects of 24-epibrassinolide on the photosynthetic characteristics, antioxidant system, and chloroplast ultrastructure in *Cucumis sativus* L. under Ca (NO 3) 2 stress. *Photosynthesis Research*, 112, 205-214.
14. Shu, S., Tang, Y., Yuan, Y., Sun, J., Zhong, M., & Guo, S. (2016). The role of 24-epibrassinolide in the regulation of photosynthetic characteristics and nitrogen metabolism of tomato seedlings under a combined low temperature and weak light stress. *Plant physiology and biochemistry*, 107, 344-353.
15. Clouse, S. D., Langford, M., & McMorris, T. C. (1996). A brassinosteroid-insensitive mutant in *Arabidopsis thaliana* exhibits multiple defects in growth and development. *Plant physiology*, 111(3), 671-678.
16. Sehrawat, N., Yadav, M., Sharma, A. K., Kumar, V., & Bhat, K. V. (2019). Salt stress and mungbean [*Vigna radiata* (L.) Wilczek]: effects, physiological perspective and management practices for alleviating salinity. *Archives of Agronomy and Soil Science*, 65(9), 1287-1301.
17. Polash, M. A. S., Sakil, M. A., Tahjib-Ul-Arif, M., & Hossain, M. A. (2018). Effect of salinity on osmolytes and relative water content of selected rice genotypes. *Trop Plant Res*, 5(2), 227-232.
18. El-Bassiouny, H. M., & Bekheta, M. A. (2005). Effect of salt stress on relative water content, lipid per oxidation, polyamines, amino acids and ethylene of two wheat cultivars. *Int. J. Agric. Biol*, 7(3), 363-368.
19. Fazari, A., Palloix, A., Wang, L., Yan Hua, M., Sage-Palloix, A. M., Zhang, B. X., & Djian-Caporalino, C. (2012). The root-knot nematode resistance N-gene co-localizes in the Me-genes cluster on the pepper (*Capsicum annuum* L.) P9 chromosome. *Plant Breeding*, 131(5), 665-673.





Aamir Abdullah et al.,

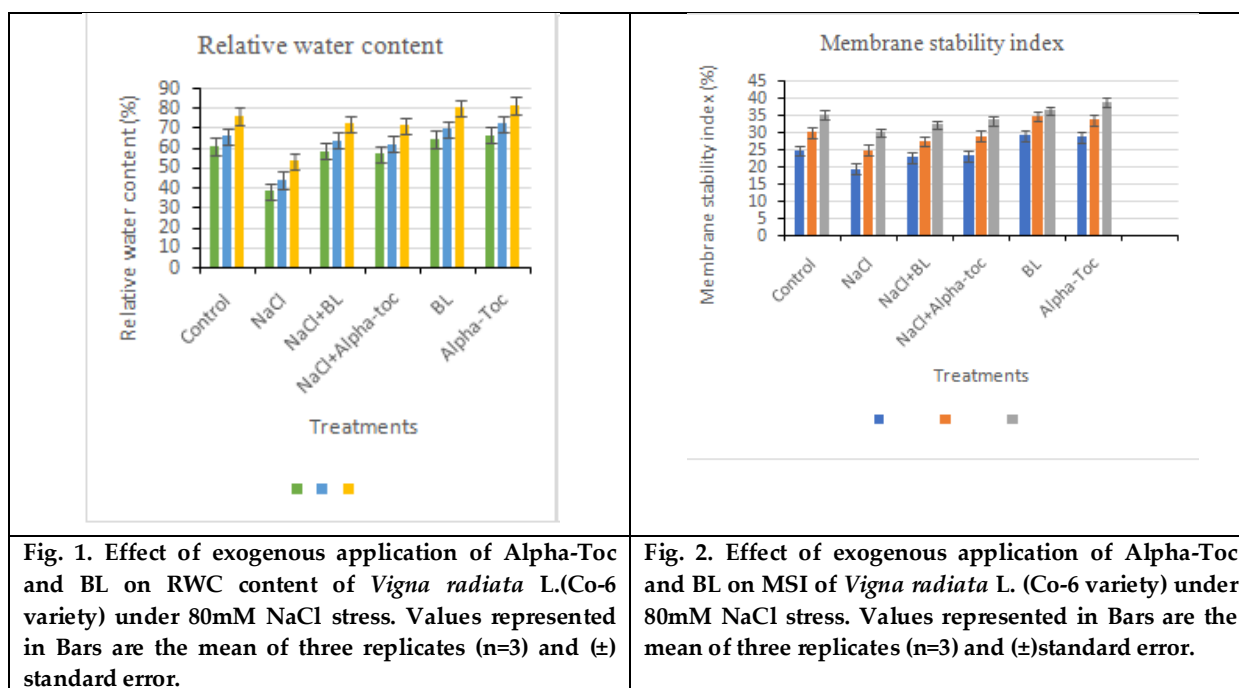
20. Su, Q., Zheng, X., Tian, Y., & Wang, C. (2020). Exogenous brassinolide alleviates salt stress in *Malus hupehensis* Rehd. by regulating the transcription of NHX-Type Na⁺ (K⁺)/H⁺ antiporters. *Frontiers in plant science*, 11, 38.
21. Karlidag, H., Yildirim, E., & Turan, M. (2011). Role of 24-epibrassinolide in mitigating the adverse effects of salt stress on stomatal conductance, membrane permeability, and leaf water content, ionic composition in salt stressed strawberry (*Fragaria× ananassa*). *Scientia horticulturae*, 130(1), 133-140.
22. Ali, Q., Ali, S., Iqbal, N., Javed, M. T., Rizwan, M., Khaliq, R., ... & Ahmad, P. (2019). Alpha-tocopherol fertigation confers growth physio-biochemical and qualitative yield enhancement in field grown water deficit wheat (*Triticum aestivum* L.). *Scientific reports*, 9(1), 12924.
23. Akram, N. A., Bashir, R., Ashraf, G., Bashir, S., Ashraf, M., Alyemeni, M. N.& Ahmad, P. (2023). Exogenous α -Tocopherol Regulates the Growth and Metabolism of Eggplant (*Solanum melongena* L.) under Drought Stress. *Plants*, 12(2), 237.
24. Shahid, M. A., Balal, R. M., Pervez, M. A., Abbas, T., Ashfaq, M., Ghazanfar, U,& Mattson, N. S. (2012). Differential response of pea (*Pisum sativum*L.) Genotypes to salt stress in relation to the growth, physiological attributes antioxidant activity and organic solutes. *Australian Journal of Crop Science*, 6(5), 828-838.
25. Semida, W. M., & Rady, M. M. (2014). Presoaking application of propolis and maize grain extracts alleviates salinity stress in common bean (*Phaseolus vulgaris* L.). *Scientia Horticulturae*, 168, 210-217.
26. Khan, A. R., Hui, C. Z., Ghazanfar, B., Khan, M. A., Ahmad, S. S., & Ahmad, I. (2015). Acetyl salicylic acid and 24-epibrassinolide attenuate decline in photosynthesis, chlorophyll contents, and membrane thermo-stability in tomato (*Lycopersicon esculentum* Mill.) under heat stress. *Pak. J. Bot*, 47(1), 63-70.
27. Talaat, N. B., Shawky, B. T., & Ibrahim, A. S. (2015). Alleviation of drought-induced oxidative stress in maize (*Zea mays* L.) plants by dual application of 24-epibrassinolide and spermine. *Environmental and Experimental Botany*, 113, 47-58.
28. Mansour, M. M. F., & Salama, K. H. (2004). Cellular basis of salinity tolerance in plants. *Environmental and Experimental Botany*, 52(2), 113-122
29. Ashraf, M., & Ali, Q. (2008). Relative membrane permeability and activities of some antioxidant enzymes as the key determinants of salt tolerance in canola (*Brassica napus* L.). *Environmental and Experimental Botany*, 63(1-3), 266-273
30. Houimli, S. I. M., Denden, M., & Mouhandes, B. D. (2010). Effects of 24-epibrassinolide on growth, chlorophyll, electrolyte leakage and proline by pepper plants under NaCl-stress. *EurAsian Journal of BioSciences*, 4.
31. Orabi, S. A., & Abdelhamid, M. T. (2016). Protective role of α -tocopherol on two *Vicia faba* cultivars against seawater-induced lipid peroxidation by enhancing capacity of anti-oxidative system. *Journal of the Saudi Society of Agricultural Sciences*, 15(2), 145-154.
32. Denaxa, N. K., Nomikou, A., Malamos, N., Liveri, E., Roussos, P. A., & Papatotriopoulos, V. (2022). Salinity effect on plant growth parameters and fruit bioactive compounds of two strawberry cultivars, coupled with environmental conditions monitoring. *Agronomy*, 12(10), 2279.
33. Hakim, M. A., Juraimi, A. S., Hanafi, M. M., Ismail, M. R., Rafii, M. Y., Islam, M. M., & Selamat, A. J. J. A. P. S. (2014). The effect of salinity on growth, ion accumulation and yield of rice varieties. *JAPS: Journal of Animal & Plant Sciences*, 24(3).
34. Ali, Q., Ali, S., Iqbal, N., Javed, M. T., Rizwan, M., Khaliq, R.,& Ahmad, P. (2019). Alpha-tocopherol fertigation confers growth physio-biochemical and qualitative yield enhancement in field grown water deficit wheat (*Triticum aestivum* L.). *Scientific reports*, 9(1), 12924.
35. Ahmad, H., Hayat, S., Ali, M., Ghani, M. I., & Zhihui, C. (2017). Regulation of growth and physiological traits of cucumber (*Cucumis sativus* L.) through various levels of 28-homobrassinolide under salt stress conditions. *Canadian Journal of Plant Science*, 98(1), 132-140.
36. Matysik, J., Alia, Bhalu, B., & Mohanty, P. (2002). Molecular mechanisms of quenching of reactive oxygen species by proline under stress in plants. *Current Science*, 525-532.
37. Szabados, L., & Savaouré, A. (2010). Proline: a multifunctional amino acid. *Trends in plant science*, 15(2), 89-97.





Aamir Abdullah et al.,

38. Kafi, M., & Rahimi, Z. (2011). Effect of salinity and silicon on root characteristics, growth, water status, proline content and ion accumulation of purslane (*Portulaca oleracea* L.). *Soil Science and Plant Nutrition*, 57(2), 341-347.
39. Yavuz, D., Kılıç, E., Seymen, M., Dal, Y., Kayak, N., Kal, Ü., & Yavuz, N. (2022). The effect of irrigation water salinity on the morph-physiological and biochemical properties of spinach under deficit irrigation conditions. *Scientia Horticulturae*, 304, 111272.
40. Naveen, Naveen & Kumari, Nisha & Avtar, Ram & Jattan, Minakshi & Ahlawat, Sushil & Rani, Babita & Malik, Kamla & Sharma, Anubhuti & Singh, Manjeet. (2021). Evaluation of Effect of Brassinolide in *Brassica juncea* Leaves under Drought Stress in Field Conditions. *Horticulturae*. 7. 514. 10.3390/horticulturae7110514.
41. Naqve, M., Wang, X., Shahbaz, M., Fiaz, S., Naqvi, W., Naseer, M., ... & Ali, H. (2021). Foliar spray of alpha-tocopherol modulates antioxidant potential of okra fruit under salt stress. *Plants*, 10(7), 1382.
42. Amirjani, M. R. (2010). Effect of salinity stress on growth, mineral composition, proline content, antioxidant enzymes of soybean. *American Journal of Plant Physiology*, 5(6), 350-360.
43. Parvaneh, R., Shahrokh, T., & Meysam, H. S. (2012). Studying of salinity stress effect on germination, proline, sugar, protein, lipid and chlorophyll content in purslane (*Portulaca oleracea* L.) leaves. *Journal of Stress Physiology & Biochemistry*, 8(1), 182-19.
44. Mansour, M. M. F., & Ali, E. F. (2017). Evaluation of proline functions in saline conditions. *Phytochemistry*, 140, 52-68.
45. Hu, Y., Xia, S., Su, Y., Wang, H., Luo, W., Su, S., & Xiao, L. (2016). Brassinolide increases potato root growth in vitro in a dose-dependent way and alleviates salinity stress. *BioMed Research International*, 2016.
46. Li, K. R., Wang, H. H., Han, G., Wang, Q. J., & Fan, J. (2008). Effects of brassinolide on the survival, growth and drought resistance of *Robinia pseudoacacia* seedlings under water-stress. *New Forests*, 35(3), 255-266.
47. AL-Kazzaz, A. G. M., & AL-Kareemawi, I. H. K. (2021). Foliar Spraying Alpha Tocopherol Enhances Salinity Stress Tolerance in Wheat Plant *Triticum Aestivum* L. *Ibn AL-Haitham Journal for Pure and Applied Sciences*, 34(3), 10-16.





Aamir Abdullah et al.,

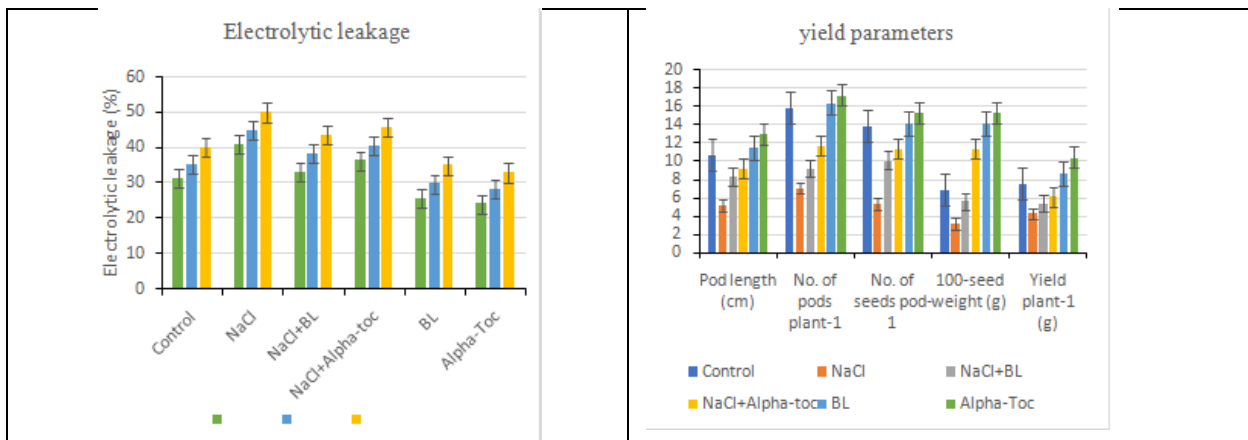


Fig. 3. Effect of exogenous application of Alpha-Toc and BL on electrolytic leakage of *Vigna radiata* L. (Co-6 variety) under 80mM NaCl stress. Values represented in Bars are the mean of three replicates (n=3) and (±) standard error.

Fig. 4. Effect of exogenous application of Alpha-Toc and BL on yield parameters of *Vigna radiata* L. (Co-6 variety) under 80mM NaCl stress. Values represented in Bars are the mean of three replicates (n=3) and (±) standard error.

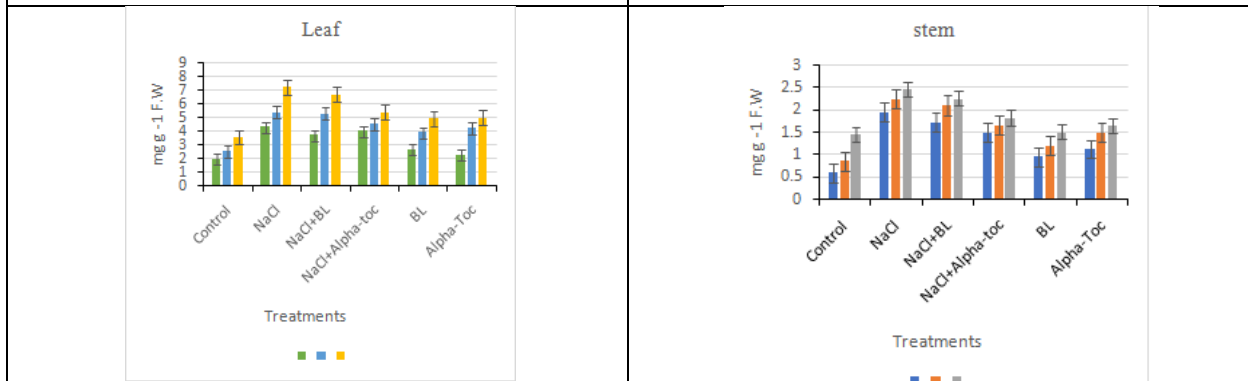


Fig. 5. Effect of exogenous application of BL and Alpha-toc on Proline content in leaf of *Vigna radiata* L. (Co-6 variety) under 80mM NaCl stress. Values represented in Bars are mean of three replicates (n=3) and (±) standard error.

Fig. 6. Effect of exogenous application of BL and Alpha-toc on Proline content in stem of *Vigna radiata* L. (Co-6 variety) under 80mM NaCl stress. Values represented in Bars are mean of three replicates (n=3) and (±) standard error.

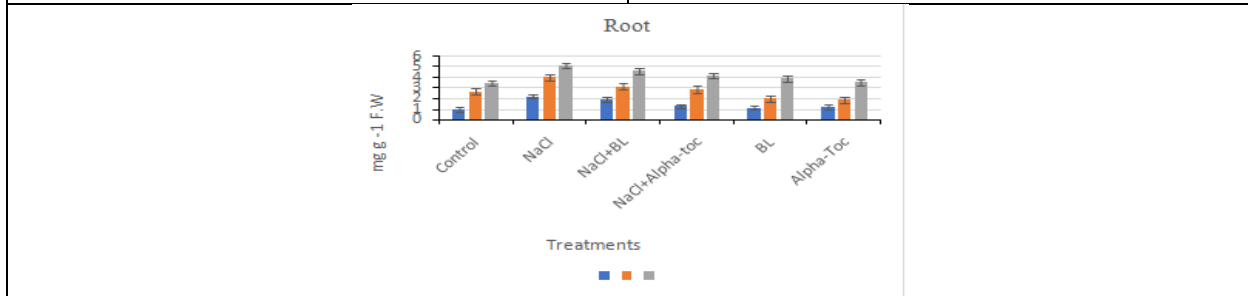


Fig. 7. Effect of exogenous application of BL and Alpha-toc on Proline content in Root of *Vigna radiata* L. (Co-6 variety) under 80mM NaCl stress. Values represented in Bars are mean of three replicates (n=3) and (±) standard error.





Sustainable Agriculture Practices in Thanjavur: Addressing Challenges in Traditional Paddy Farming and Marketing

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ABSTRACT

Organic agriculture has expanded significantly in terms of land area, farms, and sales. The Green Revolution's focus on high-yielding, input-responsive varieties displaced numerous traditional rice types. India, known for its rich rice biodiversity, has lost a substantial number of rice varieties since the 1970s. In today's organic farming practices, traditional paddy (rice) varieties are valued for their sustainability and resilience. These varieties are often better suited to local climate conditions, require fewer resources, and are more nutrient-rich compared to hybrid rice varieties. The region of Tamil Nadu, particularly the Cauvery delta zone, plays a vital role in traditional paddy cultivation. The study finds the challenges faced by traditional paddy farmers in Thanjavur district, Tamil Nadu, focusing on both production and marketing aspects. Field surveys conducted in March and April 2023 provide insights into the complex landscape of traditional paddy cultivation in the region.

Keywords: Traditional Paddy, Production, Marketing, Problem





INTRODUCTION

The organic farming movement has so far been a success, mostly. Measured in land area, number of farms, or product sales, organic agriculture has experienced stunning growth over the past few decades [1]. Organic farms face many challenges, such as land use rights, a lack of business networks, and government subsidies [2]. People all over the world, especially in many parts of Asia, depend on rice as one of their main foods, and hundreds of millions of people's lifestyles, diets, and economies have all been influenced by rice [3]. The Green Revolution's emphasis on high-yielding and input-responsive varieties replaced many important traditional varieties [4]. Several traditional rice varieties that were commonly cultivated before the Green Revolution have gone extinct, resulting in a decline in the availability of local rice varieties. According to Vedic evidence, India has over 200,000 rice types, a rice biodiversity that no other country has [5]. Almost 1 lakh types of Indian rice have been lost since 1970 [6], and currently, there are over 7000 local rice varieties, although each variety has a different quality and nutritional value [7]. Traditional paddy varieties are cultivated under organic farming today [8], and these paddy fields are regarded as valuable local resources due to their sustainable cultivation methods and their ability to serve numerous functions [9]. There are several different types of traditional paddy grown in India, and some varieties are more resistant to climate change and stressors while using fewer resources to grow. The use of TPVs with reduced input requirements not only contributes to environmental protection but also enhances the affordability of agriculture for small and marginal farmers. Traditional rice varieties are much more nutritious compared to hybrid rice varieties [10], because they have a lot of fibre and a lot of minerals and vitamins, like niacin, thiamine, iron, riboflavin, vitamin D, and calcium [11]. These traditional paddy varieties are frequently well-adapted to local climatic conditions. Furthermore, incorporating indigenous foods into the diet fosters greater food diversity and enriches diets with essential micronutrients, promoting health benefits through interactions between inherited genes and food nutrients [12].

During ancient times, the region of Tamil Nadu cultivated around 400 landraces of paddy. In the realm of Tamil literature, there are records of rice varieties that not only displayed exceptional health benefits but also held remarkable medicinal and healing properties. According to Nammazhvar, an expert in organic farming, it has been reported that there were over 400 traditional varieties of paddy in Tamil Nadu. Nel Jayaraman, a prominent farmer specialising in traditional paddy cultivation in the delta region of Tamil Nadu, has undertaken the task of gathering and preserving 300 of these types, providing them as a resource for another farmer [13]. In Tamil Nadu, traditional paddy cultivation is a significant practice for small-scale farmers, but the most significant contribution to paddy cultivation comes from the Cauvery delta zone. The delta zone of Tamil Nadu, which includes the districts of Trichy, Thanjavur, Nagapattinam, and Thiruvavur, is popularly known for its rice cultivation practices. Some studies mentioned 42,000 acres of traditional paddy varieties cultivated in the Delta Zone. The various studies mentioned aspects of traditional paddy, like Sathya's 2014 [14] study on traditional paddy based on colour, appearance, size, shape, etc. An historic Tamil literary work, Pallu Pattu, refers to around 150 paddy landraces, demonstrating its significant agricultural roots. The North Arcot area is known to host more than one hundred distinct types of rice, while the Ramanathapuram district in Tamil Nadu boasts over one hundred accessible rice varieties. In ancient times, around 400 landraces of paddy were cultivated [15]. The main issue with traditional paddy varieties is low yield and long duration, while on the other side, new varieties are high yield and short duration [16]. For this reason, a number of people change their behaviour and practices from traditional paddy to high yielding varieties. There is a gap between the present generation's knowledge about the benefits, availability of markets, and methods of cooking [17]. In recent years, Tamil Nadu has faced problems due to the mismatching of names and the duplication of traditional paddy varieties [18]. In order to study these views, specific objectives were set to investigate the problems faced in the production and marketing of traditional paddy among the farmers.

MATERIALS AND METHODS

Rice is the predominant crop in Tamil Nadu, and Thanjavur district was chosen due to its status as the largest rice cultivator, making a significant contribution to traditional paddy varieties in the state. We conducted field surveys to





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evaluate the production of traditional paddy varieties throughout the district, and we discovered that farmers were cultivating them on a small scale in various locations. To gather data, we employed a convenient sampling technique, surveying 100 farmers. Primary data collection focused on understanding production and marketing constraints during March and April of 2023.

Garrett's ranking technique

Garrett's ranking technique was used to analyze the constraints faced by the farmers in production and marketing of traditional paddy. From a policy perspective, research on the challenges faced by farmers is crucial. The respondents were asked to rank (in the order of severity) the constraints, and these ranks were converted into scores by referring to Garrett's Table.

Per cent position = $100 (R_{ij} - 0.50) / N_j$

Where,

R_{ij} = Rank given for i th item by j th individual

N_j = Number of items ranked by j th individual.

The per cent position of each rank was converted into scores by referring to tables given by Garret and Woodworth (1969) [19]. Then for each factor, the scores of individual respondents were summed up and divided by the total number of respondents for whom scores were gathered. The mean scores for all the factors were ranked, following the decision criterion that lower the value; the more serious is the constraint to farmers.

RESULTS AND DISCUSSIONS

The collected data were compiled, tabulated, and analysed to achieve the study's objectives. Organic farming, while environmentally sustainable and beneficial in many ways, comes with its own set of challenges for farmers. These challenges can be categorised into problems related to production and marketing. Farmers who practice traditional paddy (rice) farming can encounter several challenges and problems in their agricultural operations. Traditional paddy farming typically involves traditional methods and non-mechanised methods and practices. The specific problems faced by traditional paddy farmers can vary depending on the region and local conditions, but here are some common challenges mentioned in (Table 1).

Production aspects of problem in cultivation of traditional paddy

Traditional paddy farming methods often require a significant amount of manual labour, including planting, weeding, and harvesting. Farmers may struggle to find and afford skilled labour for these tasks, resulting in lower rice yields compared to modern, mechanised farming practices. This can lead to reduced income and food security for farmers. Require effective water management to control flooding and ensure proper irrigation and less effective methods for pest and disease control, which can lead to crop losses. Face challenges in accessing credit and financial resources to invest in improved farming practices, seeds, and equipment. Maintaining soil fertility can be a challenge in traditional paddy farming. Traditional paddy farming is often more vulnerable to the impacts of climate change, including erratic rainfall patterns, extreme weather events, rising temperatures, and significant losses of rice due to pests, spoilage, and poor storage conditions. Lack of skills for sustainable agricultural practice. In the study, significant problems affecting the production of traditional paddy were identified using the Garrett ranking method. The problems were ranked as follows, based on their severity: low yield (64.62), high labour requirements (60.65), pest and disease issues (53.58), concerns related to soil health and fertility (49.70), unavailability of quality seeds (48.90), limited adoption of best practices (48.32), susceptibility to climatic vulnerabilities (46.98), lack of knowledge and skills (46.90), insufficient access to credit and finance (45.92), and post-harvest losses (39.50)

Marketing aspects of problem faced by farmers in traditional paddy

Marketing traditional paddy (rice) can pose significant challenges for farmers, particularly those engaged in traditional paddy practices. These marketing-related problems can affect the income and livelihoods of farmers. Farmers often face price volatility in the paddy market, and limited markets face small-scale farmers in rural areas





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due to the absence of market information. The quality of certification is absent, the cost of transporting it far from the market is very high, and there is a lack of access to proper post-harvest processing and storage facilities. Farmers may struggle to access credit or financing to invest in better storage facilities, transportation, or marketing activities that could improve their competitiveness. Traditional paddy farmers may miss out on value-added opportunities, such as processing and packaging, which could allow them to capture a larger share of the market value. In (Table 1) common challenges encountered by farmers in marketing traditional paddy in Thanjavur. These challenges are manifest in various ways and include price fluctuations (62.14), elevated transportation costs (57.31), absence of government policies (55.53), limited awareness (50.07), inadequate access to market information (48.61), constrained credit facilities (47.49), involvement of intermediaries (46.89), adherence to quality standards (46.15), and restricted market access (43.18). The study highlighted multifaceted challenges faced by traditional paddy (rice) farmers in both production and marketing aspects. Organic farming, while environmentally beneficial, presents hurdles that can impact farmers' livelihoods. In production, these farmers grapple with labour-intensive practices, resulting in lower yields and financial constraints. Inefficient water management, limited access to credit, and climate change vulnerability further compound their challenges. The severity of these issues was quantified through Garrett ranking, highlighting concerns such as low yields and labour intensity. On the marketing front, price fluctuations, inadequate market access, and limited information availability affect income and livelihoods. Farmers often face difficulties in accessing financing for storage and transportation. They miss value-added opportunities due to financial and technical supports. Traditional paddy farmers may benefit from government support programmes, access to credit and microfinance, extension services, and capacity-building initiatives that promote sustainable and modernised farming practices. Promoting the adoption of traditional rice varieties, efficient water management systems, and better access to markets can also help enhance the livelihoods of traditional paddy farmers. Additionally, community-based organisations and agricultural cooperatives can play a role in providing support and resources to these farmers. By overcoming marketing challenges and adopting strategies to improve market access and marketing practices, traditional paddy farmers can enhance their income and overall economic well-being.

REFERENCES

1. Clark, S. (2020). Organic farming and climate change: The need for innovation. *Sustainability*, 12(17), 7012.
2. Abdalla, T. A. O., & Chen, Y. (2021). A case study on the opportunity and challenges faced by organic farming in Jiangsu Province. *Agroecology and Sustainable Food Systems*, 45(9), 1327-1374.
3. Gnanamanickam, S. S., & Gnanamanickam, S. S. (2009). Rice and its importance to human life. *Biological control of rice diseases*, 1-11. <http://thesoftcopy.in/2020/10/30/traditional-paddy-farmers-want-better-policies/>
4. Nelson, A. R. L., Ravichandran, K., & Antony, U. (2019). The impact of the Green Revolution on indigenous crops of India. *Journal of Ethnic Foods*, 6(1), 1-10.
5. Deb, D., & Bhattacharya, D. (2005). *Seeds of tradition, seeds of future: Folk rice varieties of Eastern India*. Research Foundation for Science, Technology, and Ecology.
6. The Hindu. From 1,10,000 varieties of rice to only 6,000 now. India: The Hindu; 2012. <http://www.thehindu.com/news/national/karnataka/from-110000-varieties-of-rice-to-only-6000-now/article3284453.ece>
7. Fukagawa, N. K., & Ziska, L. H. (2019). Rice: Importance for global nutrition. *Journal of nutritional science and vitaminology*, 65(Supplement), S2-S3.
8. Kabilan, M., Manickam, S., Vincent, S., & Senthilkumar, G. (2022). Evaluation of traditional rice cultivars under various cultivation practices.
9. Fukamachi, K. (2017). Sustainability of terraced paddy fields in traditional satoyama landscapes of Japan. *Journal of Environmental Management*, 202, 543-549.
10. Bhat FM, Riar CS. Health benefits of traditional Rice varieties of temperate regions. *Med Aromatic Plants*. 2015;4(3):198
11. Umadevi M, Pushpa R, Sampathkumar KP, Bhowmik D. Rice-traditional medicinal plant. *India J PharmacognPhytochem*. 2012;1(1):6–12.





Santhakumar et al.,

12. Neeha VS, Kinth P. Nutrigenomics research: a review. *J Food Sci Technol*. 2013;50(3):415–28
13. Santhakumar, S., Ravichandran, S., Venkataraman, R., and Manimaran, S. Traditional paddy cultivation in the coastal villages of Nagapattinam district: An economic analysis. *Indian J. Applied & Pure Bio*. Vol.38(3), 1188-1198 (2023).
14. Sathya A, The art of naming traditional rice varieties and landraces by ancient Tamils, *Asian Agri Hist*, 18 (1) (2014) 5-21
15. Ramaswami., A, Tamil Nadu District Gazetteers: Ramanathapuram, Madras: Director of Stationery and Printing, (1972).
16. Bowonder B. Impact analysis of the green revolution in India. *Technol Forecast Soc Chang*. 1979;15:297–313.
17. Nakamura T, Nakamura Y, Sasaki A, Fujii M, Shiota K, Mimura Y, Okamoto S. Protection of Kyo-yasai (heirloom vegetables in Kyoto) from extinction: a case of Sabaka-daikon (Japan 's heirloom white radish, *Raphanus sativus*) in Maizuru, Japan. *J Ethn Foods*. 2017;4(2):103–9.
18. Amudha, K., Geetha, S., Manimekalai, M., &Ganesamurthy, K. (2023). Rice landraces of Tamil Nadu—a review. *Indian Journal of Traditional Knowledge (IJTK)*, 22(1), 17-29.
19. Garrett EH, Woodworth RS (1969). Statistics in psychology and education. Vakils, Feffer and Simons Pvt. Ltd., Bombay, Pp. 329.

Table 1:Ranking constraints associated with production and marketing of traditional Paddy

Production Constraints														
S. no	Factor	Rank										Total Score	Mean score	Rank
		1	2	3	4	5	6	7	8	9	10			
1	Low Yield	28	1	16	26	1	10	3	0	5	10	6462	64.62	1
2	Limited Practice	26	10	14	14	5	4	6	1	14	6	4832	48.32	6
3	Pest &Disease	10	7	11	13	12	15	16	0	10	6	5358	53.58	3
4	High Labours Required	12	15	1	6	10	11	14	11	11	9	6065	60.65	2
5	Lack of Credit & Finance	3	8	7	7	23	9	6	14	7	16	4592	45.92	9
6	Soil Health & Fertility	8	11	16	13	9	13	6	11	6	7	4970	49.70	4
7	Climate Vulnerability	1	16	13	9	8	6	8	20	13	6	4698	46.98	7
8	Post-Harvest Losses	7	19	6	4	4	10	14	9	13	14	3950	39.50	10
9	Unavailability of Varieties	4	12	6	7	12	11	19	12	10	7	4890	48.90	5
10	Lack of Knowledge & Skill	1	1	10	1	16	11	8	22	11	19	4690	46.90	8
Marketing Constraints														
1	Price Variation	31	1	19	1	7	4	9	18	3	7	6214	62.14	1
2	Limited Market Access	15	11	11	9	7	15	7	7	13	5	4318	43.18	10
3	High Transport Cost	9	7	11	10	9	12	7	17	8	10	5731	57.31	2
4	Quality tandards	12	7	15	10	14	8	7	6	11	10	4615	46.15	9
5	Lack of Market Information	6	8	8	12	12	13	6	14	11	10	4861	48.61	5
6	Less Awareness	6	12	15	8	11	10	10	7	7	14	5007	50.07	4
7	Intermediaries	8	6	6	12	8	7	18	9	15	11	4689	46.89	8
8	No Government Policy	4	16	3	17	11	10	13	9	7	10	5553	55.53	3
9	Credit Facilities	6	13	7	10	8	13	10	9	12	12	4749	47.49	7
10	Value-Added Opportunities	3	19	5	11	13	8	13	4	13	11	4763	47.63	6

Source: Field Survey

Total number of sample respondent's 100





Kinematic and Geotechnical Assessment of Vulnerable Slopes and Geotechnical Properties of Soil in Zunheboto Sadar, Zunheboto District Nagaland

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ABSTRACT

The Rock Mass Rating basic (RMR_b), kinematic analysis and geotechnical properties of soil finds extensive use in the field of geotechnical engineering. In the specific region under investigation, RMR_b serve the purpose of characterizing rock masses whereas kinematic analysis predicts potential modes of slope failure by considering the geometry of rock discontinuities and their orientation relative to the slope face. The Rocscience Dips 7.0 software was used to conduct the kinematic analysis. The components of RMR_b encompass Uniaxial Compressive Strength (UCS), Rock Quality Designation (RQD), Discontinuity Condition, Discontinuity Spacing and Groundwater conditions. Ensuring the stability of rock slopes along roads and highways is a significant concern in the mountainous study area. The paper covers the study of RMR_b and kinematic analysis of some vulnerable slope in Zunheboto Sadar area of Zunhebo to District, Nagaland along with the examination of geotechnical characteristics of soil such as Moisture Content, Wet Density, Dry Density, Porosity, Void ratio, Volume of Void, Volume of Solid, Specific Gravity, Angle of Internal Friction, Cohesion, Unconfined Compressive Strength, Liquid Limit, Plastic Limit and Plasticity Index.

Keyword: Geotechnical, Kinematic analysis, RQD, UCS, RMR_b





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INTRODUCTION

Landslides are recognized as among the most perilous natural disasters, leading to persistent road blockages, infrastructure impairment, the loss of agricultural land, damage to buildings, and, in certain instances, loss of lives [1]. Slope failures are triggered by a variety of external factors, such as tectonic forces, weathering and erosion processes, and human activities, particularly in steep mountainous regions [2]. The stability of rock slopes is frequently affected by the geological structures inherent in the rock formations from which the slope is excavated. Geological structures encompass naturally occurring fractures like joints and faults, as well as bedding planes commonly referred to as discontinuities. The significance of discontinuities lies in their role as planes of weakness within the considerably stronger intact rock, making failure more likely to occur along these surfaces. Almost all investigations into rock slope stability must delve into the structural geology of the site. Such studies aim to discern the impact of discontinuities on stability by examining the relationship between the orientation of these fractures and the slope face [3].

Rock Mass Rating basic (RMR b) is an essential tool for characterizing rock masses, widely used in planning and design for engineering applications. RMR was introduced by Bieniawski in 1973 and subsequently modified several times. In this study, five components of the RMR b system were included as developed by Bieniawski (1989), they are; Uniaxial Compressive Strength (UCS), Rock Quality Designation (RQD), Discontinuity Condition, Discontinuity Spacing, and Groundwater conditions. [4] The Rock Quality Designation (RQD) is one of the most important parameters for assessing RMR b. [5]

Kinematic analysis, being purely geometric, proves highly valuable in assessing the locations and types of failures, along with their directions, in jointed rock masses. The angular correlations between discontinuities and slope surfaces, known as rock formation dip, are used to identify possible areas for slope failures and their associated failure modes. [6] Geotechnical properties of soil are critical in understanding and predicting the behavior of soil under various conditions. These properties influence the design, construction, and stability of structures such as buildings, roads, dams, and embankments. The evaluation of soil engineering properties is crucial in addressing a variety of geotechnical engineering challenges. Shear strength tests are particularly important for determining soil's shear strength characteristics. The soil's shear strength is characterized by cohesion (C) and the friction angle (ϕ). These parameters predominantly determine the soil's maximum capacity to resist shear stress under a given load. [7]

Study area

The study area, Zunheboto Sadar, as illustrated in *figure 1*, is situated within the Zunheboto district of Nagaland state, India. It falls within the Toposheets No. 83 J/8, 83 J/12, 83 K/9 and 83 K/5 encompassing an approximate area of 123 km². This hilly terrain features dense forest cover and elevations ranging from 642 meters to 1989 meters. The Langki River bounds it in the west, while the Tizu River borders it to the east. Owing to its elevation and location, the area experiences a moderate humid subtropical climate, featuring cold winters and significantly warm rainy summers.

Geological Settings

The geology of Zunheboto district includes rocks from the Barail Group and the Disang Group of rocks. The Disang Group, being the older litho-unit, consists of a substantial and uniform sequence of splintery and nodular grey shale, interspersed with minor layers of sandstone, siltstone, and occasional intraformational conglomerate beds.[8][9]The Lower Disang formation is characterized by dark grey to greenish-grey argillaceous shale, alternating with slender layers of grey siltstone and fine-grain sandstone. In contrast, the Upper Disang formation consists of dark grey splintery shale with an arenaceous nature, interspersed with sandy shale and siltstone.[10] [11]Laterally and vertically, the Barail group overlays the lithological units of the Disang group. The Barail group consists of extensive sequences of sandstone interspersed with extremely thin, papery shale layers, spanning from the Upper Eocene to



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Oligocene age. Overlying the Disang group, the Barail group is characterized by the Laisong Formation lithounits, featuring multi-storeyed sandstones with varying shale-siltstone interbands.[12]The geological map along with the Soil, RMR_b and Kinematic analysis location have been shown in figure 2.

MEDTHODOLOGY

In the field, observations and measurements of discontinuity orientations such as bedding planes, faults, joints, and slope faces were directly conducted. These observed discontinuities were then analyzed using Dips 7.0 software for kinematic analysis. Based on the data collected in the study area, RMR_b studies were carried out. Examination of geotechnical characteristics of soil such as Moisture Content, Wet Density, Dry Density, Porosity, Void ratio, Volume of Void, Volume of Solid, Specific Gravity, Angle of Internal Friction, Cohesion, Unconfined Compressive Strength, Liquid Limit, Plastic Limit and Plasticity Index were carried out in the selected location (ZS1 to ZS16). The Atterberg limits of soil samples which include liquid limit and plastic limit were determined as per (IS: 2720-5, 1985). Cohesion (c) and internal friction angle (ϕ) for soils were determined as per IS: 2720 part 13 (1986). The Unconfined Compressive Strength (UCS) of soil test was performed as per IS 2720 (Part 10): 1991 (Reaffirmed 2020). The specific gravity test of soil solids is followed as per the IS:2720 (part 4)-1985.

Rock Mass Rating

Rock Mass Rating Classification entails grouping a rock mass into various classes or categories based on defined relationships, and assigning a distinct descriptor or numerical value to it based on similar properties or characteristics. This process enables the prediction of the behavior of the rock mass.[4]In the study area RMR_b studies was carried out in 15 locations i.eKR1 to KR15. RMR_b was calculated by summing the ratings of five rock mass properties (Table 2) measured at various places as per Bieniawski, 1989. These parameters include UCS, RQD, Discontinuity Condition, Discontinuity Spacing, and Groundwater Conditions.The UCS was obtained from the field assessmentof rock strength using the method of ISRM, 1981. [13]

Kinematic analysis

Kinematic analysis was performed to demonstrate the possibility for several types of rock slope failures (such as plane and wedge failures) caused by unfavorably orienteddiscontinuities. The analysis was carried out using Markland's test as the basis.[14] Thekinematic analysis involves three key parameters: the orientation of structural discontinuities (joints), the orientation of the slope, and the angle of internal friction (ϕ). The pertinent data on the structural discontinuities of the rock mass was subsequently subjected to kinematic analysis to comprehend the potential modes of rock slope failure at different locations using Dips 7.0. The kinematic data for locations KR1 to KR15 is presented in Table1

Geotechnical properties of soil

Soil samples were gathered from various locations in the study area, labelled from ZS1 to ZS16. The sample is allowed to pass through the 425 μ m mesh sieve for the test of Liquid Limit, Plastic Limit, Specific gravity and Plasticity index. For UCS, Direct shear test and Density test, the soil is made to pass through 4.75 mm mesh sieve. The sample is dried inside the oven for the determination of wet and dry density of the soil. Preparation cylindrical specimens with a length 7.6 cm and diameter 3.8 cm i.e ratio of 2:1 for soil Unconfined compressive strength ensuring the ends of the specimens is flat and perpendicular to the axis. Trimming the soil sample to fit the shear box, ensuring it has a flat surface for the direct shear. The shear parameter results for the soil samples are presented in Table 3, while Table 4 displays the geotechnical properties of the soil.



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RESULTS AND DISCUSSION

With reference to the field assessment of rock strength using the method of ISRM 1989, in the study area, the Barail Sandstone is categorized as R-4 grade (strong), indicating a UCS range of 50-100 MPa and the Disang Shale falls into the R-3 grade (medium strong) signifying UCS values within the range of 25-50 MPa. The RMR_b values in the study area ranges from 37 to 69 suggesting that the exposed rock masses at the site are classified as Poor rock, Fair rock and Good rock, falling into Class-IV and Class-III and Class II respectively. Out of 15 locations of RMR_b , the location KR9 and KR10 fall in class IV which corresponds to the poor rock, both of these has damp ground water condition and low RQD. Although most of the rock slopes appear stable through RMR_b studies during field observations, they may be susceptible to slope failure based on kinematic analysis, especially with any slope modifications or natural gravitational forces. The rock cut slopes in the area exhibit wedge, planar, and combined types of failures, but no locations have been identified with toppling failure as a potential mode of failure.

The rock slope in the location KR1, KR9, KR10 and KR14 and KR15 are mostly susceptible to wedge failure. Based on the Rose diagram *figure 8*, the general trend of S0 strike NE-SW and dips moderately towards NW and it is undulatory in nature and shows moderately smooth surface with clay filling within the aperture openings.

The result of geotechnical analyses of soil samples reveals that dry density of the soil ranges from 1.30 gm/cm³ to 1.83 gm/cm³. wet density ranges from 1.60 gm/cm³ to 2.11 gm/cm³. Specific gravity ranges from 2.25 to 2.54. Volume of solid ranges from 45.69 cm³ to 70.01 cm³. Volume of void ranges from 16.67 cm³ to 40.49 cm³. Void ratio ranges from 0.23 to 0.89. Porosity ranges from 18.76% to 46.98%. Moisture content ranges from 15.44% to 28.84%. The cohesion of Soil ranges from 0.12 to 0.20 Kg/cm². Angle of internal friction ranges from 8° to 22°. Unconfined Compressive strength ranges from 0.80 Kg/cm² to 2.2 Kg/cm² with sample ZS9 being the highest. Liquid limit ranges from 36% to 63%. Plastic limit ranges from 10% to 33%. Plasticity index ranges from 15% to 47%. The relationship between moisture content and cohesion indicates a decrease in cohesion with an increase in moisture content in the specimen. The fluctuation in moisture content of the soil is directly linked to its porosity and is influenced by the structural arrangement of the soil particles. Soils with elevated moisture content typically exhibit poorer packing of grains, leading to larger voids, whereas lower moisture content indicates denser packing. Consequently, an increase in moisture content in soil results in a decrease in its shear strength values. [15] In some areas there is small range between the plastic limit (PL) and liquid limit (LL) which indicates that the soil can quickly transition from a semi-solid to a liquid state with the addition of water. This transition leads to decrease in Cohesion, Reduction in the Angle of Internal Friction and Lower Bearing Capacity of the soil. Additionally, the specific gravity of the soil in the research area ranges from 2.25 to 2.54, indicating the absence of organic matter or heavy substances, as all values fall between 2.0 and 3.0.[16]

CONCLUSION

The study area encompassing an approximate area of 123 km² where majority of the population in Zunheboto is concentrated. The rock types found in the study area belongs to the Barail Group and the Disang Group, where Disang shales from Disang group covers more than 80% of the research area. RMR_b assessments for selected slope cuts in the study area were conducted due to the significance of the region and the evolving pattern of LULC, which could pose threats to slopes and potentially result in the loss of life and property. The rock mass exhibits a high degree of jointing and, in some areas, foliation. The rock slopes predominantly feature three to four sets of joints, and their structural data have been extensively collected through fieldwork in the research area. Based on the Rose diagram, the general trend of S0 is NE-SW and dips moderately towards NW and it is undulatory in nature and shows moderately smooth surface with clay filling within the aperture openings. The RMR_b values in the study area ranges from 37 to 69 suggesting that the exposed rock masses at the site are classified as Poor rock, Fair rock and Good rock, falling into Class-IV and Class-III and Class II respectively. Geotechnical analyses of rock samples reveals



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that the increase and decrease in moisture content of the soil is directly related to the porosity and is a result of structural configuration of the soil particles.

REFERENCES

1. Alimohammadlou Y, Najafi A, Yalcin A. Landslide process and impacts: A proposed classification method. *Catena* 2013;104:219-32.
2. Viridi, N.S., Sah, M.P. and Bartarya, S.K. Project Report: Landslide Hazard Zonation in the Beas and Satluj Valleys of Himanchal Pradesh, Phase-I Satluj Valley. Wadia Institute of Himalayan Geology Technical Report, 1995;132-144
3. Wyllie, D., Mah, C. Rock slope engineering: civil and mining. Taylor and Francis Group. London and New York 2005:1-52.
4. Bieniawski, Z.T. Engineering rock mass classifications: a complete manual for engineers and geologists in mining, civil, and petroleum engineering. John Wiley & Sons 1989:40-47
5. Zhang, L. (2015) Determination and applications of rock quality designation (RQD). *Jour. Rock Mech. Geotech. Engg.*, pp.5.
6. RK, U., Singh, R., Ahmad, M. and TN, S. Stability analysis of cut slopes using continuous slope mass rating and kinematic analysis in Rudraprayag district, Uttarakhand. *Geomaterials*, 2011.
7. Bláhová, K., Ševelová, L. and Pilařová, P. Influence of water content on the shear strength parameters of clayey soil in relation to stability analysis of a hillside in Brno region. *Acta Universitat is Agriculturae et Silviculturae Mendelianae Brunensis* 2013;61(6):1583-1588.
8. Srivastava, M. P., Prasad K.S and Ray, B. Systematic geological mapping in parts of Zunheboto district, Nagaland. Progress Report, Geological Survey of India 1985-86.
9. Mallet, F.R. On the coal fields of Naga hills bordering the Lakhimpur and Sibsagar districts. *Assam. Mem. Geol. Surv. India*, 1876;12(2):166-363.
10. Sinha, N.K., Chatterjee, B.P. and Satsangi, P.P. Status of paleontological researches in the Northeastern states of India. *Rec. Geol. Surv. India* 1982;112(4):66-88.
11. Agrawal OP, Ghose NC. Geology and stratigraphy of the Naga Hills ophiolite between Melluri and Awankhoo, Pheek District, Nagaland, India. In Indian chapter IGCP Projects 195 and 197. Meeting 1986:163-195.
12. Ganju, J.L., Khar, B.M. and Chaturvedi, J.G. Geology and hydrocarbon prospects of Naga Hills south of 27 latitude. *Bulletin. Oil and Natural Gas Commission* 1986;23(2):129-145.
13. International Society for Rock Mechanics (ISRM) (1981) "Rock Characterization Suggested Method, Testing and Monitoring," London, Pergamon Press.
14. Hoek, E. and Bray, J.W. *Rock Slope Engineering*. Revised 3rd Edition, The Institution of Mining and Metallurgy, London 1981:341-351.
15. Zydroń, T. and Dąbrowska, J. The influence of moisture content on shear strength of cohesive soils from the landslide area around Gorlice. *AGH Journal of Mining and Geoenvironment* 2012;36(2):309-317.
16. Sharma, L. K., Umrao, R. K., Singh, Rajesh., Ahmad, M. and Singh, T. N. Geotechnical characterization and stability evaluation of hill cut soil slopes along highway: a case study. *INDOROCK 2016: 6th Indian Rock Conference* 2016:17-18.





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Table1: Results of Kinematic Analysis.

Rock slope/outcrop	Foliation (S0)		Joint set (J1)		Joint set (J2)		Joint set (J3)		Joint set (J4)		Failure Mode	
	Strike (Right)	Dip	Strike (Right)	Dip	Strike (Right)	Dip	Strike (Right)	Dip	Strike (Right)	Dip	Planar	Wedge (Plunge/direction)
KR1	315	45	25	53	110	85	280	85	---	---	J1	S0^J1 (42/69) S0^J3 (31/96) J1^J2 (53/117) J1^J3 (51/92)
KR 2	345	64	80	46	310	25	---	---	---	---	J2	---
KR 3	275	30	100	65	265	34	25	53	---	---	J3	J1^J3 (50/135)
KR 4	20	75	95	48	290	60	----	----	---	---	S0	S0^J1 (47/182)
KR 5	290	20	340	85	50	60	---	---	---	---	J2	J1^J2 (58/151)
KR 6	295	25	290	45	325	80	---	---	---	---	---	J1^J2 (33/332)
KR 7	270	20	100	65	200	30	---	---	---	---	J2	J1^J2 (27/265)
KR 8	55	20	245	70	155	80	---	---	---	---	---	J1^J2 (66/307)
KR 9	225	55	85	64	90	80	50	48	110	80	---	S0^J1 (28/249) S0^J2 (39/261) S0^J4 (49/277)
KR 10	215	80	100	80	215	50	---	---	---	---	---	S0^J1 (29/248) S0^J2 (39/262) S0^J4 (49/279)
KR 11	45	35	150	45	30	25	---	---	---	---	J2	J1^J2 (44/270)
KR 12	25	42	220	60	30	40	---	---	---	---	---	S0^J2 (33/156)
KR 13	33	25	239	55	35	30	---	---	---	---	J1	---
KR 14	180	81	293	42	190	70	---	---	---	---	J2	S0^J1 (37/350) S0^J2 (41/351) S0^J4 (37/353)
KR15	105	50	98	62	330	80	250	55	---	---	---	J2^J3 (54/342)

Table 2: Calculation of RMR_b for 15 locations of the study area (after Bieniawski;1989)

Rock slope/outcrop	UCS (MPa)	RQD (%)	Spacing (mm)	Condition of discontinuities					Ground Water condition	RMR _b	Class	Description
				Persistence (m)	Separation (mm)	Roughness	Infilling (mm)	Alteration/Weathering				
KR1	25-50	49	190	10	1	Slightly rough surfaces	None	Moderately weathered	Dry			
	4	8	8	2	4	3	6	3	15	53	III	Fair Rock
KR2	50-100	78.7	230	5	1	Slightly rough surfaces	Hard filling <5 mm	Moderately weathered	Dry			
	7	17	10	2	4	3	4	3	15	65	II	Good Rock





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KR3	50-100	82	220	2	1	SlightlyRough	Hard filling <5 mm	Slightly weathered	Dry			
	7	17	10	4	4	3	4	5	15	69	II	Good Rock
KR4	25-50	42.4	250	7	5	Slightlyrough surfaces	Soft filling <5mm	Slightly weathered	Dry			
	4	8	10	4	1	3	2	5	15	52	III	FairRock
KR5	25-50	45.7	120	6	5	Slightly rough surfaces	Hard filling <5 mm	Slightly weathered	Dry			
	4	8	8	2	1	3	4	5	15	50	III	FairRock
KR6	25-50	45.7	220	7	5	Slightly rough surfaces	None	Moderately weathered	Dry			
	4	8	10	2	1	3	6	3	15	52	III	FairRock
KR7	50-100	49	250	6	1	Slightly rough surfaces	Soft filling <5mm	Slightly weathered	Dry			
	7	8	10	2	4	3	2	5	15	56	III	Fair Rock
KR8	25-50	55.6	300	8	3	Slightly rough surfaces	None	Moderately weathered	Dry			
	4	13	10	2	1	3	6	3	15	57	III	Fair Rock
KR9	25-50	39.1	< 60 mm	3	5	Slightly rough surfaces	Soft filling <5mm	Moderately weathered	Damp			
	4	8	5	2	1	3	2	3	10	38	IV	Poor Rock
	(MPa (%)	(%)	(mm)	Persistence (m)	Separation (mm)	Roughness	Infilling (mm)	Alteration/Weathering				
KR10	25-50	35.8	< 60 mm	11	5	Slightly rough surfaces	Soft filling <5mm	Moderately weathered	Damp			
	4	8	5	1	1	3	2	3	10	37	IV	Poor Rock
KR11	50-100	78.7	450	1-3m	<0.1 mm	Slightly rough surfaces	Soft filling <5mm	Moderately weathered	Dry			
	7	17	10	4	5	3	2	3	15	66	II	Good Rock
KR12	50-100	55.6	190	9	0.1-1.0	Slightly rough surfaces	Soft filling <5mm	Moderately weathered	Dry			
	7	13	8	2	4	3	2	3	15	57	III	Fair Rock
KR13	25-50	25.9	80	12	4	Slightly	Hard	Slightly weathered	Dry			





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						rough surfaces	filling <5 mm					
	4	8	8	1	1	3	4	5	15	49	III	Fair Rock
KR14	50-100	42.4	160	10	5	Slightly rough surfaces	None	Slightly weathered	Dry			
	7	8	8	1	1	3	6	5	15	54	III	Fair Rock
KR15	25-50	35.8	150	15	3	Slightly rough surfaces	None	Slightly weathered	Dry			
	4	8	8	1	1	3	6	5	15	51	III	Fair Rock

Table 3: The geotechnical results of shear parameters of soil samples.

Sample No.	C(Kg/cm2)	(Ø) (degree)	UCS (Kg/cm2)
ZS1	0.12	21	2.1
ZS2	0.13	10	1
ZS3	0.16	12	1.2
ZS4	0.13	20	2
ZS5	0.15	13	1.3
ZS6	0.19	10	1
ZS7	0.2	9	0.9
ZS8	0.15	21	2.1
ZS9	0.14	22	2.2
ZS10	0.14	18	1.8
ZS11	0.16	13	1.3
ZS12	0.14	12	1.2
ZS13	0.17	12	1.2
ZS14	0.12	8	0.8
ZS15	0.16	15	1.5
ZS16	0.17	14	1.4

Table 4: Geotechnical properties of soil samples.

Sample No.	Moisture Content %	Dry Density (gm/cm ³)	Wet density (gm/cm ³)	Sp. gravity	Volume of solid (cm ³)	Volume of Void (cm ³)	Void ratio (e)	Porosity %	Liquid limit %	Plastic limit %	Plasticity index %
ZS1	28.84	1.47	1.89	2.53	50.03	36.15	0.72	41.95	63	16	47
ZS2	26.52	1.52	1.93	2.49	52.73	33.45	0.63	38.82	55	25	30
ZS3	25.18	1.38	1.73	2.48	48.04	38.14	0.79	44.26	38	14	24
ZS4	22.58	1.30	1.60	2.31	48.66	37.52	0.77	43.54	53	19	34
ZS5	17.62	1.78	2.09	2.54	60.30	25.88	0.43	30.03	41	12	29
ZS6	16.10	1.81	2.10	2.34	66.54	19.64	0.30	22.79	54	29	25
ZS7	15.44	1.83	2.11	2.25	70.01	16.17	0.23	18.76	36	10	26
ZS8	19.38	1.73	2.06	2.31	64.46	21.71	0.34	25.20	42	23	19





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ZS9	19.54	1.58	1.89	2.29	59.44	26.73	0.45	31.02	44	26	18
ZS10	22.58	1.30	1.60	2.46	45.69	40.49	0.89	46.98	51	27	24
ZS11	15.44	1.83	2.11	2.36	66.74	19.43	0.29	22.55	37	22	15
ZS12	24.18	1.39	1.73	2.46	48.81	37.37	0.77	43.36	48	32	16
ZS13	18.58	1.74	2.06	2.47	60.69	25.48	0.42	29.57	41	16	25
ZS14	21.55	1.45	1.77	2.52	49.74	36.43	0.73	42.28	53	33	20
ZS15	21.59	1.64	1.99	2.50	56.40	29.77	0.53	34.55	48	27	21
ZS16	21.55	1.45	1.77	2.45	51.16	35.01	0.68	40.63	47	30	17

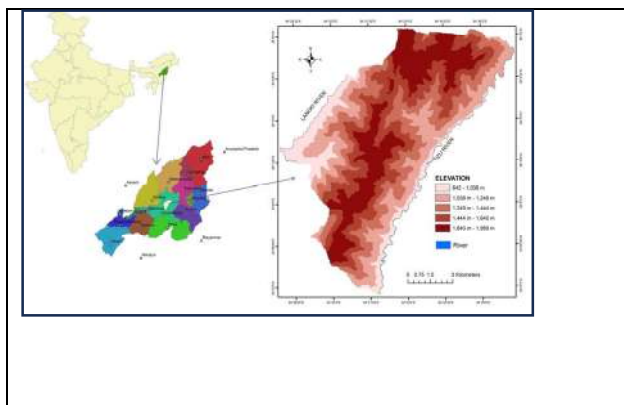


Figure 1. Location of the study area.

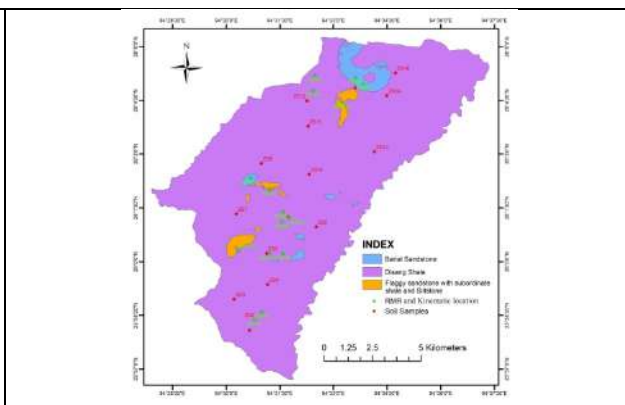


Figure 2. Geological map along with the sample locations.



Figure 3. Planar and wedge failure of RMR15



Figure 4. planar and wedge failure of RMR15

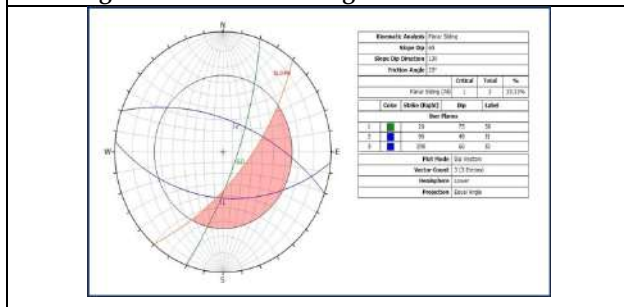


Figure 5. RMR4 wedge mode of failure

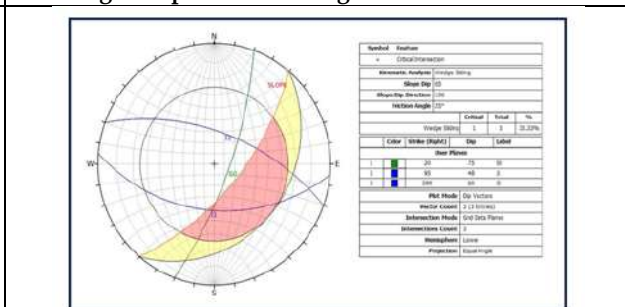


Figure 6. RMR4 wedge mode of failure





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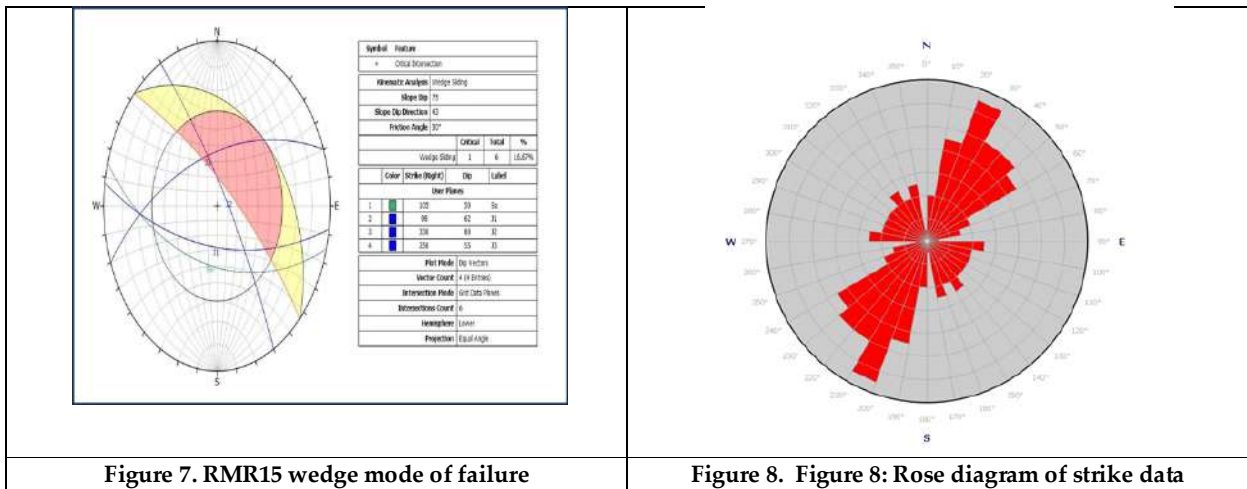


Figure 7. RMR15 wedge mode of failure

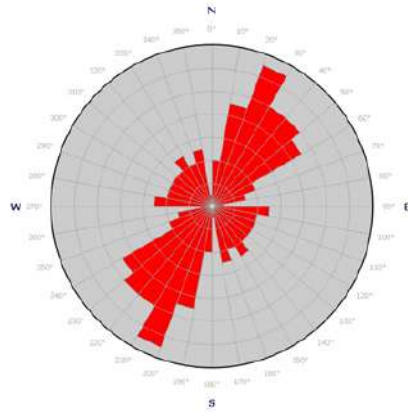


Figure 8. Figure 8: Rose diagram of strike data





Evaluation Neuro-Protective Effects of *Erythrina variegata* towards Aluminium Chloride (AlCl₃) Induced Oxidative Stress of Alzheimer's Disease in Rat Model"

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ABSTRACT

Alzheimer's disease (AD) is a progressive neurological disorder that gets worsen over time. As per reports, aluminium is a strong neurotoxin that can cause and hurry beta-amyloid aggregation, cholinergic corruption, neuronal passing, oxidative harm to the cerebrum and lacks in memory and learning. This study was conceptualized to evaluate the neuroprotective activities of *Erythrina variegata* extracts against aluminium chloride (AlCl₃) induced neurotoxicity in rat model. The Morris water maze and Open field test were performed in this review to research how functioning, spatial, and acknowledgment memory were impacted by the drawn-out treatment of AlCl₃. locomotory and exploratory examples of Alzheimer Rodents were likewise assessed partly as an open field test. Endogenous antioxidant activity, CAT, SOD, and GSH action were performed and furthermore the histopathological appraisals of the different Cerebrum areas specifically cortex and hippocampus were performed. The current concentrate obviously features the neuroprotective activity of AqEEV and MetEEV against AlCl₃-incited deficiencies. AqEEV

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and MetEEV had the option to invert AlCl₃-instigated neurobehavioral debilitations and mental shortages, including working, spatial, and acknowledgment cognitive decline, alongside other locomotor hindrances. In the mind's cortex and hippocampus, they diminished the oxidative pressure brought about by AlCl₃, particularly the movement of nitric oxide (NO) and reactive oxygen species (ROS). Histological investigations uncovered that AqEEV and MetEEV could capture neuronal degeneration. Therefore, AqEEV and MetEEV are viewed as therapeutic treatments for AD that are effective.

Keywords: Alzheimer's disease , beta-amyloid , *Erythrina variegata*, Neurodegenerative disease, Memory impairment and locomotory actions .

INTRODUCTION

The presence of extracellular neurofibrillary tangles and intracellular amyloid accumulations characterize Alzheimer's-disease (AD), an age-related persistent neuro-degenerative disease (1). Short-term memory loss characterizes the early stages of AD, which are accompanied by an increasing range of additional symptoms including mood and behavior changes, hostility, disorientation, social distancing and long-term memory loss (2). The primarily dysregulated pathways linked to the advancement of AD include oxidative stress, inflammation and apoptosis. These variables have been shown to have a very negative effect and are closely linked to several neurodegenerative diseases (3). The key players in the activation of several downstream signalling molecules, including MAPKs are reactive oxygen species (ROS). The persistent loss of neural and synaptic activities that leads to a decline in memory and cognition is known as AD. The two main histopathological features of AD are thought to be the buildup of intracellular neurofibrillary knots and the deposition of amyloid-beta-peptides (Ab) in the nerve cells (4). *Erythrina variegata* (EV) India is home to this small, medium-sized, deciduous tree in the Fabaceae family. It has prickly stems and branches, leaves with three-sided pamphlets and enormous coral red blossoms. The plant's bark has astringent, febrifuge, hostile to bilious, and anthelmintic properties. Furthermore, it assists with skin conditions and ophthalmia (5). The flavonoids, alkaloids and triterpenoids that make up EV's phytochemicals have been utilized as a sedative, neuroprotective and nerve tonic (6). One well-known neurotoxin implicated in the genesis of AD is aluminium (7). This metal is generally accessible in the world and can undoubtedly enter the human body through acid neutralizers, water, food added substances, cutlery, antiperspirants and drugs. Aluminium generally gets deposited in the cerebrum and hippocampus, two region of the mind that are known to be particularly weak in AD (8). It causes cytoskeleton protein misfolding, which causes tau neurofibrillary tangles and amyloid beta plaques to form in the brain (9) (10). Because aluminium is a strong cholinotoxin it can lead to neurodegeneration and apoptotic neuronal loss as well as cognitive dysfunction (11). Cholinergic activity is frequently expected for the learning and recovery of memory and abilities to learn (12). As a result, individuals with AD typically exhibit decreased performance on a range of cognitive tasks (13). Numerous animal studies have demonstrated that extended exposure to aluminium can alter brain chemistry, behavior, and pathology, which affects rats' capacity for learning (14). In light of EV's potential therapeutic uses, a preclinical study was designed to assess the memory-enhancing effects of Aqueous extract (AqEEV) and Methanolic extract (MetEEV) of EV in a mouse model of cognitive dysfunction and oxidative damage induced by (AlCl₃).

MATERIALS AND METHOD

Experimental animals

The animals were Adult Wistar Rats (200-250 g body weight) that were acquired from CCSEA registered breeder. All the animals were acclimatized for one week with light/dull cycle (12/12 h) and were given water and typical pellet diet. Farooqia College of Pharmacy's Institutional Animal Ethics Committee approved the studies (Approval Number-IAEC/FCP/02/2021)) and all animal procedures were done in accordance with CCSEA guidelines.





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Neuroprotective studies

Following the acclimatization period, Wistar Albino Rats were classified as fast, medium, or slow learners based on performance on Morris Water Maze (MWM) task during the trial period. The animals were randomized and divided into 9 group containing 6 animals in each group. The treatment and evaluation were performed as shown in **Table 1**

N=6, AqEEV-Aqueous extract of Erythrina variegata; MetEEV-Methanolic extract of extract of Erythrina variegata; p.o- per oral.

Assessment of neuroprotective effects

Morris water maze

The MWM test was used to evaluate spatial memory (15). Escape latency time (ELT), number of entries (NEs) to original platform location and time spent in target quadrant (TSTQ) was utilized as a mark of memory maintenance.

Open field test

To evaluate the animal's behavioural and locomotor activities, an open field test was performed in 16 (4 x 4) square wooden apparatuses recorded the observations. Squares investigated and total time spent motionless were recorded (16).

Biochemical assay

Assessment of endogenous antioxidant

The levels of catalase (CAT), glutathione (GSH), superoxide dismutase (SOD) and lipid peroxidation (LPO) were estimated utilizing the cerebrum homogenate.

Assessment of Acetylcholine esterase (AChE) Assay

Ellman's method was used to perform AChE activity (17) and protein concentration was estimated according to Lowry's technique (18).

Histopathology

All of the groups Rats brains were separated and kept in a 10% formalin solution. The brain samples were then regularly cleansed in xylene, embedded in paraffin and treated in increasing concentrations of alcohol. Nissl stain was applied after coronal sections with a thickness of 5–6 m was cut, mounted and stained.

Statistical analysis

Using SPSS version 20, the findings were analysed and presented as Mean±SEM. One-way ANOVA was used in the statistical analysis, and TUKEY post hoc was used for multiple group comparisons. A probability value that was deemed to be statistically significant was $p < 0.05$.

RESULTS

Protective effects of AqEEV and MetEEV against AlCl₃ toxicity by MWM task

Reducing ELT and boosting NEs and TSTQ were among the possible nootropic effects of nootropic agents. Animals treated with AlCl₃ alone have shown significant increase in ELT, reduced NEs and TSTQ when compared with normal group of animals, which demonstrates the AlCl₃ neurotoxicity. Whereas the extracts AqEEV and MetEEV have shown the reversal of AlCl₃ toxicity by decreasing ELT and increasing NE and TSTQ dose dependently when compared with control group of animals. It was observed that, low dose of both the extracts have shown least activities (Figure 1).

Locomotor activity of AqEEV and MetEEV by Open field test.

The control group showed higher rearing, longer immobility times and fewer squares crossed when compared with that of normal group of animals. Treatment with tested extracts and standard have shown significant dose dependent improved locomotion, decreased immobility and lessened rearing when compared with control group of animals. Additionally, both extracts dramatically reduced fecal pellets, which may have benefits for cognition. All things



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considered, AqEEV, MetEEV and piracetam showed encouraging nootropic activities by enhancing locomotor activity and reducing aberrant behaviours in Rats (Figure 3).

3.3 Morphological parameter (Body weight)

The control group animals shown a significant weight reduction when compared to normal group whereas, Rats treated with AqEEV and MetEEV showed a significant weight increase, as did treated with piracetam ($p < 0.05$). These findings suggest that AqEEV, MetEEV, and piracetam may influence rodent body weight, indicating potential physiological effects (Figure 5).

Biochemical Parameters**Endogenous antioxidant enzyme activity (CAT, SOD GSH and MDA)**

The administration of $AlCl_3$ significantly reduced antioxidant enzyme activities (CAT, SOD, GSH) in rats' brains compared to the normal group, indicating increased oxidative stress. In contrast, AqEEV and MetEEV significantly elevated CAT, SOD, and GSH activities, highlighting their antioxidant properties. The reference compound also ameliorated antioxidant enzyme activities. MDA levels, indicative of lipid peroxidation, altogether higher in $AlCl_3$ -presented rodents contrasted with the normal group. AqEEV and MetEEV dose-dependently decreased MDA levels, akin to the control group and piracetam-treated rats. These results suggest that AqEEV and MetEEV possess antioxidant potential, mitigating oxidative stress induced by $AlCl_3$.

3.5 Histopathological examination**Gross Appearance**

Histopathological studies of Rats treated with $AlCl_3$ and regular treatment with AqEEV and MetEEV is shown in the **Figure 6**. Normal morphology of neuron was observed in hippocampus region. Foci of apoptosis and condensation of nucleus observed in CA3 region of hippocampus – [granular type cells apoptosis] – red arrows were observed in control group. Standard group showed normal morphology of neuron were observed in hippocampus region. Whereas, increased dose of AqEEV and MetEEV (400mg/kg) treatment exhibited a normal morphology of neurons observed in hippocampus.

Normal

Section studied shows cerebral cortex composed of pyramidal cells, fusiform cells, granular cells, oligodendrocytes and neuroglial cells in neurofibrillary matrix [neuropil]. The pyramidal cells and granular cells appear intact. The blood vessels appear intact and within normal limits.

Control group ($AlCl_3$ 100mg/kg)

Section studied shows cerebral cortex composed of pyramidal cells, granular cells, oligodendrocytes and neuroglial cells against a neurofibrillary matrix [neuropil]. The pyramidal cells [severe] show apoptosis with halo around the cell along with granular cell degeneration [moderate]. Mild lymphocytic infiltration with thrombosed blood vessels is also noted.

Standard group (Piracetam 500mg/kg)

Section studied shows cerebral cortex composed of pyramidal cells, fusiform cells, granular cells, oligodendrocytes and neuroglial cells in neurofibrillary matrix [neuropil]. The pyramidal cells [mild] show apoptosis with halo around the cell along with granular cell degeneration [mild]. The blood vessels are congested at few places. Inflammation is not observed.

AqEEV 100 mg/kg

Section studied shows cerebral cortex composed of pyramidal cells, fusiform cells, granular cells, oligodendrocytes and neuroglial cells in neurofibrillary matrix [neuropil]. The pyramidal cells [mild] show apoptosis with halo around the cell along with granular cell degeneration [moderate] are observed. Dense lymphocytic infiltration [Moderate] with congested blood vessels is noted.





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AqEEV 200mg/kg

Section studied shows cerebral cortex composed of pyramidal cells, fusiform cells, granular cells, oligodendrocytes and neuroglial cells in neurofibrillary matrix [neuropil]. The pyramidal cells [moderate] show apoptosis along with granular cell degeneration [mild]. Mild lymphocytic infiltration is noted.

AqEEV 400mg/kg

Section studied shows cerebral cortex composed of pyramidal cells, fusiform cells, granular cells, oligodendrocytes and neuroglial cells in neurofibrillary matrix [neuropil]. The pyramidal cells and granular cells appear intact. The blood vessels appear intact and within normal limits.

MetEEV 100mg/kg

Section studied shows cerebral cortex composed of pyramidal cells, fusiform cells, granular cells, oligodendrocytes and neuroglial cells in neurofibrillary matrix [neuropil]. The pyramidal cells [mild] show apoptosis with halo around the cell along with granular cell degeneration [moderate] are observed. Dense lymphocytic infiltrations [Moderate] with congested blood vessels are noted.

MetEEV 200mg/kg

Section studied shows cerebral cortex composed of pyramidal cells, fusiform cells, granular cells, oligodendrocytes and neuroglial cells in neurofibrillary matrix [neuropil]. The pyramidal cells [moderate] show apoptosis along with granular cell degeneration [mild]. Mild lymphocytic infiltrations are noted.

MetEEV 400mg/kg

Section studied shows cerebral cortex composed of pyramidal cells, fusiform cells, granular cells, oligodendrocytes and neuroglial cells in neurofibrillary matrix [neuropil]. The pyramidal cells and granular cells appear intact. The blood vessels appear intact and within normal limits.

Number of degenerated neurons

Administration of AIC13 significantly ($p < 0.05$) decreased the total neuronal count in the CA1, CA3 & DG region of Rats brain when compared to normal group. Whereas, the treatment of AqEEV and MetEEV (mild & high dose) significantly ($p < 0.05$) increased the total neuronal count. Reference compound Piracetam treated Rats produced the significant ($p < 0.05$) increase in neuronal count compared to AIC13 group (Table 03).

DISCUSSION

Alzheimer's-disease is a dynamic neurological problem that worsen with time. Aluminum gathering has been proposed as a contributing component to Alzheimer's illness, with higher aluminum focuses tracked down in the minds of Alzheimer's patients (19). Aluminum is thought to penetrate the cerebrum through transferrin such as a high-proclivity receptors and gather in the hippocampus and affects the learning and memory focus. Aluminum has been demonstrated to be a strong neurotoxin, equipped for producing and hurrying cerebrum oxidative harm, neuron demise, cholinergic corruption, beta-amyloid statement, and memory and learning issues (20). We previously discovered that *Erythrina variegata* contains triterpenoids, flavonoids, and alkaloids that are used as neuroprotective agents, febrifuges, nerve tonics and sedatives. The current and flow of investigation discovered that constant treatment of AIC13 decayed working, spatial and acknowledgment memory which was estimated by the MWM task and open field test. The time it took the AIC13-treated rodents arrive at the stage expanded while the time-spent in the objective quadrant diminished in the MWM task. Chronic AIC13 treatment has been connected to learning deficiencies in rodents in examinations. Aluminium's capacity to impede long term memory potentiating synthetic compounds like cyclic-GMP and activate aggravation in the Glutamate-NO-cGMP pathway in the Rat frontal cortex is shown by these learning shortfalls and memory disabilities (21). Spatial, working and acknowledgment memory deficiencies were turned around with medium (200 mg/kg) and higher (400mg/kg) treatments of AqEEV and





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MetEEV (22). Locomotion and exploratory examples of AD rodents were likewise assessed a piece of Open-field-test. The rodents showed significant locomotion and exploratory behaviour impedance in AlCl₃ treated animals. Past results of persistent AlCl₃ organization have also shown a decrease in locomotion, which is thought to be caused by depression in the central nervous system. With medium (200mg/kg) and higher (400mg/kg) dose of AqEEV and MetEEV treatment was supporting the corrections of the locomotion, exploratory conduct hindrances and builds the body weight. Together, these outcomes validate AqEEV, MetEEV neuroprotective job in revising mental impedances. Antioxidants are one of the promising components in forestalling the beginning and movement of AD sickness. By expanding the prooxidant actions of iron in the brain and diminishing the anti-oxidant enzyme actions the main endogenous cell reinforcements, GSH and CAT, AlCl₃ harming causes serious oxidative pressure (23). The amassing of free extremists that surpasses the limit of the cells to battle them by means of cancer prevention agents is alluded to as oxidative pressure. The status of MDA is an important biomarker of oxidative stress (24). ROS-induced lipid peroxidation, which damages membranes, causes MDA accumulation. Frequent AlCl₃ exposure enhanced MDA status while suppressing the antioxidants SOD, CAT, and GSH. The medium (200mg/kg) and large (400mg/kg) doses of AqEEV and MetEEV significantly reduced MDA levels while increasing SOD, CAT and GSH levels in brain tissues. These findings support the antioxidant properties of AqEEV and MetEEV. Histopathological studies of various brain areas, including the cortex and hippocampus, were carried out. The existence of oligodendrocytes and neuroglial cells against a neurofibrillary matrix [neuropil] was seen after a 42-day chronic treatment of AlCl₃. The medium (200mg/kg) and large (400mg/kg) doses of AqEEV and MetEEV treatment were able to reverse this pathology significantly by a significant decrease in neuronal degenerations. These discoveries support AqEEV and MetEEV capacity to switch the neurotic signs of promotion and initiate a defensive impact on cortex and hippocampal neuronal cells.

SUMMARY AND CONCLUSION

Alzheimer's disease, marked by worsening neurological issues, is associated with aluminum accumulation in the brain, contributing to neurotoxicity. *Erythrina variegata*, known for its neuroprotective compounds, was investigated for its potential in alleviating chronic AlCl₃ induced cognitive and behavioural impairments in Rats. The study revealed that AlCl₃ treatment led to memory deficits, disrupted spatial and working memory and hindered locomotion and exploratory behaviour. AqEEV and MetEEV, administered in medium and large doses, effectively reversed these deficits, showcasing their neuroprotective role. Furthermore, the treatments demonstrated antioxidant properties by reducing oxidative stress markers and enhancing antioxidant enzyme levels. Histopathological analysis indicated a significant reversal of neurodegenerative changes in the cortex and hippocampus with AqEEV and MetEEV treatment. In summary, AqEEV and MetEEV exhibit promise in mitigating AD related impairments, offering potential therapeutic benefits through their neuroprotective and antioxidant effects.

REFERENCES

1. Aguilar TAF, HernándezNavarro BC, Pérez JAM, Aguilar TAF, HernándezNavarro BC, Pérez JAM. Endogenous Antioxidants: A Review of their Role in Oxidative Stress. In: A Master Regulator of Oxidative Stress - The Transcription Factor Nrf2 [Internet]. IntechOpen; 2016 [cited 2023 Dec 28]. Available from: <https://www.intechopen.com/chapters/52680>
2. Amberla K, Nordberg A, Viitanen M, Winblad B. Long-term treatment with tacrine (THA) in Alzheimer's disease--evaluation of neuropsychological data. *Acta Neurol Scand Suppl.* 1993;149:55–7.
3. Cao Z, Wang F, Xiu C, Zhang J, Li Y. Hypericum perforatum extract attenuates behavioral, biochemical, and neurochemical abnormalities in Aluminum chloride-induced Alzheimer's disease rats. *Biomed Pharmacother Biomedecine Pharmacother.* 2017 Jul;91:931–7.
4. Exley, C., Vickers, T., 2014. Elevated brain aluminium and early onset Alzheimer's disease in an individual occupationally exposed to aluminium: A case report. *J. Med. Case Rep.* 8, 41. - Google Search [Internet]. [cited 2023 Dec 28]. Available from: [https://www.google.com/search?q=Exley%2C+C.%2C+Vickers%](https://www.google.com/search?q=Exley%2C+C.%2C+Vickers%2C)



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5. Sarkar AP, Khatun S, Enam T, Jahan MstI, Sarker A, Saha N, et al. Promising Actions of Certain Medicinal Plants of Bangladesh against Diabetes and Oxidative Stress: A Review. *Pharmacol Amp Pharm.* 2022;13(10):393–416.
 6. The Pharmacognostic and Pharmacological Studies on Medicinal Valued Herbal Drugs Erythrina Variegata Var. Orientalis, Matricaria Chamomilla, Psoralea Corylifolia and Chenopodium Album [Internet]. [cited 2023 Dec 28]. Available from: https://thesis.asianindexing.com/thesis.php?ari_id=1676727587590&title=The%20Pharmacognostic%20and%20Pharmacological%20Studies%20on%20Medicinal%20Valued%20Herbal%20Drugs%20Erythrina%20Variegata%20Var.%20Orientalis%2C%20Matricaria%20Chamomilla%2C%20Psoralea%20Corylifolia%20and%20Chenopodium%20Album&q=
 7. Canales JJ, Corbalán R, Montoliu C, Llansola M, Monfort P, Erceg S, et al. Aluminium impairs the glutamate-nitric oxide-cGMP pathway in cultured neurons and in rat brain in vivo: molecular mechanisms and implications for neuropathology. *J Inorg Biochem.* 2001 Nov;87(1–2):63–9.
 8. Protein phosphorylation regulates secretion of Alzheimer beta/A4 amyloid precursor protein. - PMC [Internet]. [cited 2023 Dec 28]. Available from: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC48802/>
 9. Cochran M, Elliott DC, Brennan P, Chawtur V. Inhibition of protein kinase C activation by low concentrations of aluminium. *Clin Chim Acta Int J Clin Chem.* 1990 Dec 24;194(2–3):167–72.
 10. Domingo JL. Aluminum and other metals in Alzheimer's disease: a review of potential therapy with chelating agents. *J Alzheimers Dis JAD.* 2006 Nov;10(2–3):331–41.
 11. Therapeutic Potential of Epigallocatechin Gallate Nanodelivery Systems - PMC [Internet]. [cited 2023 Dec 28]. Available from: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5534279/>
 12. Ehrnhoefer DE, Bieschke J, Boeddrich A, Herbst M, Masino L, Lurz R, et al. EGCG redirects amyloidogenic polypeptides into unstructured, off-pathway oligomers. *Nat Struct Mol Biol.* 2008 Jun;15(6):558–66.
 13. Ellman GL, Courtney KD, Andres V, Feather-Stone RM. A new and rapid colorimetric determination of acetylcholinesterase activity. *Biochem Pharmacol.* 1961 Jul;7:88–95.
 14. el-Sebae AH, Abdel-Ghany ME, Shalloway D, Abou Zeid MM, Blancato J, Saleh MA. Aluminum interaction with human brain tau protein phosphorylation by various kinases. *J Environ Sci Health B.* 1993 Dec;28(6):763–77.
 15. Morris R. Developments of a water-maze procedure for studying spatial learning in the rat. *J Neurosci Methods.* 1984 May;11(1):47–60.
 16. Rajasankar S, Manivasagam T, Surendran S. Ashwagandha leaf extract: a potential agent in treating oxidative damage and physiological abnormalities seen in a mouse model of Parkinson's disease. *Neurosci Lett.* 2009 Apr 17;454(1):11–5.
 17. Pohanka M, Hrabínova M, Kuca K, Simonato JP. Assessment of acetylcholinesterase activity using indoxylacetate and comparison with the standard Ellman's method. *Int J Mol Sci.* 2011;12(4):2631–40.
 18. Waterborg JH. The Lowry method for protein quantitation. In: *The protein protocols handbook.* Springer; 2009. p. 7–10.
 19. Rondeau V, Jacqmin-Gadda H, Commenges D, Helmer C, Dartigues JF. Aluminum and silica in drinking water and the risk of Alzheimer's disease or cognitive decline: findings from 15-year follow-up of the PAQUID cohort. *Am J Epidemiol.* 2009 Feb 15;169(4):489–96.
 20. Germano C, Kinsella G. Working Memory and Learning in Early Alzheimer's Disease. *Neuropsychol Rev.* 2005 Apr 1;15:1–10.
 21. Lakshmi BVS, Sudhakar M, Prakash KS. Protective effect of selenium against aluminum chloride-induced Alzheimer's disease: behavioral and biochemical alterations in rats. *Biol Trace Elem Res.* 2015 May;165(1):67–74.





Saleem Ahmed et al.,

22. Erazi H, Sansar W, Ahboucha S, Gamrani H. Aluminum affects glial system and behavior of rats. C R Biol. 2010 Jan;333(1):23–7.
23. Praticò D, Uryu K, Sung S, Tang S, Trojanowski JQ, Lee VMY. Aluminum modulates brain amyloidosis through oxidative stress in APP transgenic mice. FASEB J Off Publ Fed Am Soc Exp Biol. 2002 Jul;16(9):1138–40.
24. Endogenous Antioxidants: A Review of their Role in Oxidative Stress | IntechOpen [Internet]. [cited 2023 Dec 28]. Available from: <https://www.intechopen.com/chapters/52680>

Table 1: Grouping, treatment and study protocol.

Groups	Treatments	Evaluation parameters
Normal	0.5% Na-CMC <i>p.o.</i> (Vehicle) was administered for 42 days.	<ul style="list-style-type: none"> ▪ Spatial reference learning and memory by Morris Water Maze on 0th, 7th, 21st 28th, 35th & 43rd day. ▪ Locomotor activity by open filed test 0th, 7th, 21st 28th, 35th & 43rd day. ▪ Endogenous antioxidant level-SOD, CAT, GSH and LPO. <ul style="list-style-type: none"> ▪ AChE activity. ▪ Histopathology- Nissl stain and neuronal count
Control (AlCl ₃)	AlCl ₃ (100 mg/kg, <i>p.o.</i>) was administered for 42 days and vehicle.	
Piracetam+AlCl ₃	Piracetam (500 mg/kg, <i>p.o.</i>) daily as a suspension in the vehicle and AlCl ₃ (100 mg/kg, <i>p.o.</i>) was administered for 42 days after 2 hrs of regular treatment.	
AqEEV (100mg)+AlCl ₃	AqEEV (100 mg/kg, <i>p.o.</i>) daily as a suspension in the vehicle and AlCl ₃ was administered for 42 days after 2 hrs of regular treatment.	
AqEEV (200mg)+AlCl ₃	AqEEV (200 mg/kg, <i>p.o.</i>) daily as a suspension in the vehicle and AlCl ₃ was administered for 42 days after 2 hrs of regular treatment.	
AqEEV (400mg)+AlCl ₃	AqEEV (400 mg/kg, <i>p.o.</i>) daily as a suspension in the vehicle and AlCl ₃ was administered for 42 days after 2 hrs of regular treatment.	
MetEEV (100mg)+AlCl ₃	MetEEV (100 mg/kg, <i>p.o.</i>) daily as a suspension in the vehicle and AlCl ₃ was administered for 42 days after 2 hrs of regular treatment.	
MetEEV (200mg)+AlCl ₃	MetEEV (200 mg/kg, <i>p.o.</i>) daily as a suspension in the vehicle and AlCl ₃ was administered for 42 days after 2 hrs of regular treatment.	
MetEEV (400mg)+AlCl ₃	MetEEV (400 mg/kg, <i>p.o.</i>) daily as a suspension in the vehicle and AlCl ₃ was administered for 42 days after 2 hrs of regular treatment.	

Table 2: Protective effects of AqEEV and MetEEV endogenous antioxidant activity against AlCl₃ induced toxicity

Group	Tissue antioxidant levels			
	MDA (umol/mg of protein)	SOD (umol/mg of protein)	CAT (umol/mg of protein)	GSH (umol/mg of protein)
Normal	06.60±0.50	12.73±0.60	5.84±0.61	4.05±0.39
Control	16.06±0.83 ^a	6.073±0.20 ^a	3.36±0.04 ^a	2.23±0.25 ^a
Piracetam	09.40±0.28 ^b	12.54± 0.66 ^b	5.83±0.65 ^b	3.85±0.24 ^b





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AqEEV (100mg/kg)	15.32±0.39	7.085±0.30	3.85±0.27	2.60±0.29
AqEEV (200mg/kg)	12.73±0.37	8.95±0.39 ^c	3.16±0.81 ^c	3.64±0.53 ^c
AqEEV (400mg/kg)	09.93±0.52 ^c	11.74±0.98 ^c	5.32±0.98 ^c	4.86±0.44 ^c
MetEEV (100mg/kg)	14.27±0.70	06.38±0.21	3.11±0.45	3.03±0.27
MetEEV (200mg/kg)	12.17±0.61	09.40±0.64 ^c	4.38±0.25 ^c	3.69±0.39 ^c
MetEEV (400mg/kg)	09.34±0.7 ^c	12.32±0.68 ^c	5.82±0.37 ^c	4.63±0.37 ^c

Values are expressed as Mean± SEM. n= 6

P< 0.05, ^a significant when compared to the normal vs control group.

P< 0.05, ^b significant when compared to the control vs standard and extracts group.

P< 0.05, ^c significant when compared to the extract's vs standard.

Table 3. Protective effects of AqEEV and MetEEV by histopathological studies of degenerated neurons against AICl3 induced toxicity

Groups	CA1 Region	CA3 Region	DG Region
Normal	244.5±2.74	354.2±2.55	1089.4±10.04
Control	105.0±1.41 ^a	163.2±1.62 ^a	462.20±4.24 ^a
Piracetam	238.8±2.17 ^b	353.7±1.84 ^b	1073.2±14.41 ^b
AqEEV (100mg/kg)	110.2±2.82	171.3±1.26	482.50±6.30
AqEEV (200mg/kg)	204.7±2.15 ^c	293.2±1.92 ^c	792.80±6.97 ^c
AqEEV (400mg/kg)	233.7±1.84 ^c	346.8±3.36 ^c	1010.6±19.37 ^c
MetEEV (100mg/kg)	115.2±1.58	179.3±2.56	519.20±1.25
MetEEV (200mg/kg)	210.8±4.36 ^c	297.2±2.21 ^c	816.70±6.32 ^c
MetEEV (400mg/kg)	237.8±4.16 ^c	354.0±4.70 ^c	1021.7±10.4 ^c

Values are expressed as Mean± SEM. n= 6

P< 0.05, ^a significant when compared to the normal vs control group.

P< 0.05, ^b significant when compared to the control vs standard and extracts group.

P< 0.05, ^c significant when compared to the extract's vs standard.

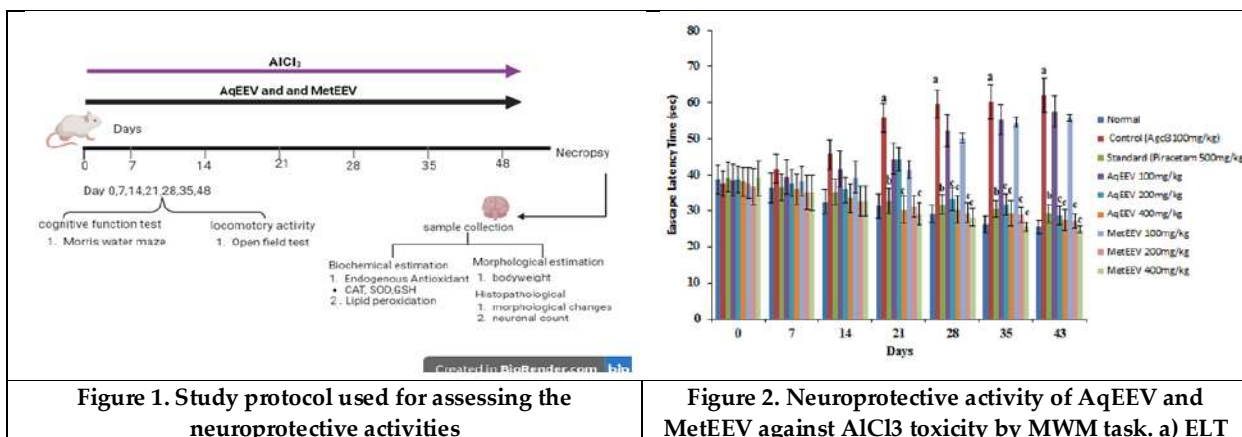


Figure 1. Study protocol used for assessing the neuroprotective activities

Figure 2. Neuroprotective activity of AqEEV and MetEEV against AICl3 toxicity by MWM task. a) ELT

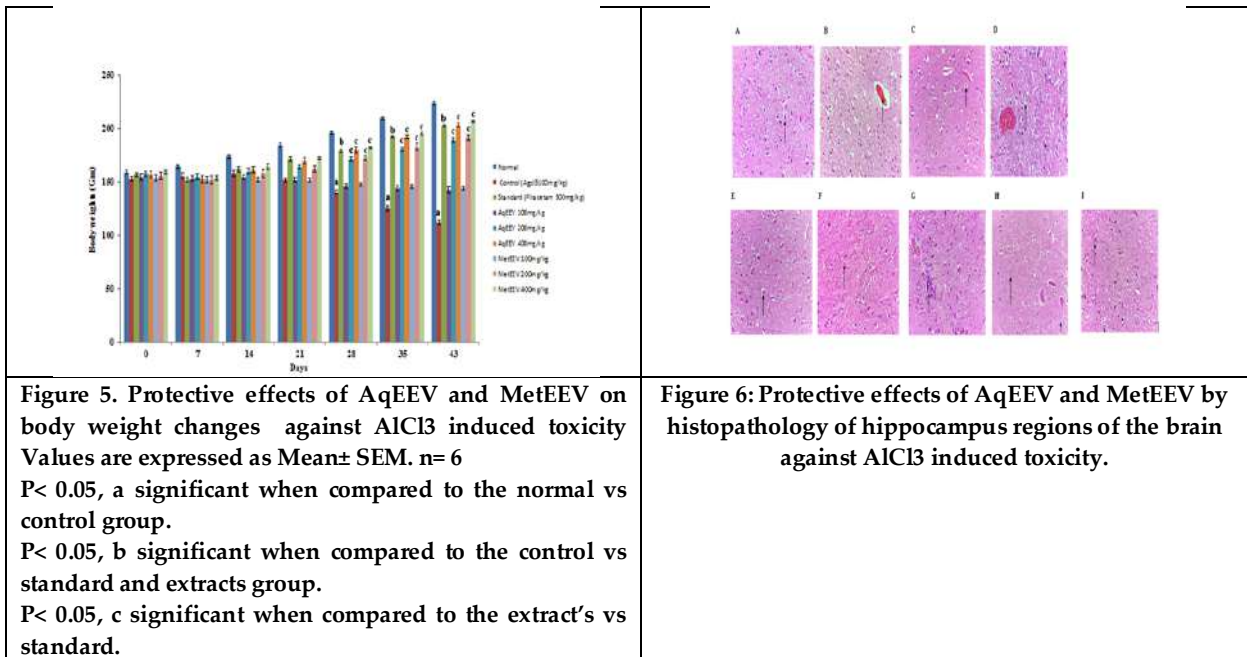




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<p align="center">Figure 2. b) NEs</p>	<p align="center">Figure 2. c) TSTQ</p> <p>Values are expressed as Mean± SEM. n= 6 P< 0.05, a significant when compared to the normal vs control group. P< 0.05, b significant when compared to the control vs standard and extracts group. P< 0.05, c significant when compared to the extract's vs standard.</p>
<p align="center">Figure 3. Protective effects of AqEEV and MetEEV by open field test a) Squares crossed</p>	<p align="center">Figure 3 b) Faecal pellets</p>
<p align="center">Figure 3 c) Immobility</p>	<p align="center">Figure 3 d) Rearing Values are expressed as Mean± SEM. n= 6 P< 0.05, a significant when compared to the control l vs norma group. P< 0.05, b significant when compared to the standard and extracts group vs. control P< 0.05, c significant when compared to the extract's vs standard.</p>







Computational Evaluation on Molecular Structure, Vibrational Assignments, Electronic Properties, NBO Analysis, Topological Analysis and Molecular Docking Study of (E)-3-(1, 3-Benzoxazol-2-ylsulfanyl)-1-Phenylprop-2-en-1-one

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ABSTRACT

Chalcone derivative (E)-3-(1, 3-benzoxazol-2-ylsulfanyl)-1-phenylprop-2-en-1-one (C1) has been identified from the GC-MS spectrum of the ethanolic extract of Kabasura Kudineer (KSK). Out of the nine phytochemicals identified, the title compound was selected for DFT study using Gaussian 16 W software with 6-311++G (d, p) basis set and tools. The optimized structure and the geometrical parameters were estimated and compared with the reported structure and are found to be in good agreement. The vibrational frequencies assignment was carried out by FTIR and FT-RAMAN spectral analysis and is in the expected range. The chemical reactivity was investigated by calculating HOMO- LUMO and band gap energies which revealed the chemical reactivity. Electrophilic and Nucleophilic attacking sites were identified by MEP surface analysis. The natural bond orbital analysis uncovered the hyperconjugative $\pi \rightarrow \pi^*$ type charge transfer across donor to acceptor atoms and helps understand the charge transfer and stabilization energy due to inter or intramolecular interactions. The electronic charge distribution and the reactive sites on the surface of the title compound were analyzed using the AIM, ELF, and LOL topological analyses. The atomic charge distribution, which affects the electronic polarizability, dipole





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moment, and electronic structure of the compound, was specified in terms of Mulliken's atomic charge analysis to uncover the D...A charge transfer and the capability of hydrogen bond formation. The biological importance of the compound particularly the anticancer activity was established by performing molecular docking with the target protein 3QQL and found to be an excellent anticancer agent with an active site binding energy of -6.56 kcal/mol.

Keywords: DFT, Vibrational assignments, HOMO-LUMO orbitals, MEP, NBO and Molecular Docking

INTRODUCTION

The outbreak of coronavirus disease (COVID-19) has been characterized as a pandemic by the World Health Organization (WHO), causing irrevocable torment and placed emphasis on public health and necessary control measures to cease the outspread of the virus [1]. With no specific or effective treatment or cure for COVID-19, potential vaccines have been inoculated for people globally [2]. Unfortunately, even persons who are fully vaccinated are diagnosed with COVID-19, leading the way for complementary or alternative medicines [3]. The usage of the Siddha formulation *Kabasura Kudineer* (KSK) on COVID-19 patients had significant control over the disease with no inimical effects and showed recommended results in the reduction of symptoms [4]. These characteristics intrigue the applications of KSK to other adverse diseases like cancer. Cancer refers to a group of diseases characterized by the development of abnormal cells with the potential to invade or spread to other parts of the body. Experimental cancer treatments are studied in clinical trials to compare the proposed treatment to the best existing treatment [5]. Confirmative anti-cancer effects have been shown by providing complementary medicine on lung cancer cell lines in recent studies [6], and thus this research work intends to investigate the possible anti-cancer effects with the help of the inhibitor with PDB ID: 3QQL. Natural and synthetic chalcones are likely to take center stage in research worldwide due to their potential uses in various fields. The basic structure of chalcones is illustrated by two aromatic rings linked by two carbon atoms connected to an unsaturated carbonyl group [7, 8]. They are leveraged the most because of their pharmacological possessions such as antifungal, antimicrobial, anti-inflammatory, and antitumor properties due to their antioxidant effects [9-11]. Biological applications of materials basically required an extensive analysis of both intra and intermolecular interactions that quantify structure-activity relations (SARs). The quantum level computations (DFT) are the most powerful tool to study the interactions between biomolecules. Computational aspects offer new testable hypotheses for regular drugs involved in the novel Coronavirus [12]. In this work, we report the results of various DFT-based investigations on the chalcone derivative (E)-3-(1,3-benzoxazol-2-ylsulfanyl)-1-phenylprop-2-en-1-one (C1) including the geometrical parameters (Table 1) in comparison with the crystal structure of the reported compound: 2-(1, 3-Benzoxazol-2-ylsulfanyl)-1-phenylethanone [13], molecular electrostatic potential distribution, Mulliken's charges, the natural bond orbital (NBO), HOMO-LUMO orbital, and band gap, surface topology in addition to stretching-bending vibrational assignments, and NLO property studies, the possible weak and non-covalent interactions via QTAIM analysis, and the suitability of the material to act as an anticancer agent along with ADMET properties by docking study in this communication.

MATERIALS AND METHODS

Gas Chromatography–Mass Spectrometry (GC-MS) of KSK

The ethanolic extract of *Kabasura Kudineer* was prepared as reported by K. Laavanya et al. [14] and the GC-MS spectrum of the *Kabasura Kudineer* (KSK) extract was obtained using the JEOL GCMATE II GC-MS with a data system provided by the Bureau Veritas India Private Ltd., Ekkattuthangal, Guindy, Chennai-32. It is specified with a maximum resolution of 6000 and a maximum calibrated mass of 1500 Daltons, and the source choices include Electron impact (EI) and Chemical ionization (CI). The GC-MS-Mass spectrum of KSK was investigated for the phytochemical constituents. Out of the nine phytochemicals, (E)-3-(1, 3-benzoxazol-2-ylsulfanyl)-1-phenylprop-2-en-1-one (C1) was selected for the DFT study.





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Computational methodology

The quantum chemical calculations and spectroscopic assessment of the title compound were done using the DFT-B3LYP level of theory with 6-311++G d, p) basis set by means of the Gaussian program package [15]. Becke's three-parameter hybrid function (B3) for the exchange part was combined with the Lee-Yang-Parr (LYP) correlation function [16]. The structure was optimized to minimum energy, and the intramolecular forces were brought to zero without any geometric restraints. The geometric parameters, such as bond angle and bond length, were obtained using the Chemcraft software. The theoretical vibrational frequencies were assigned based on the potential energy distribution analysis using the VEDA 4 program. The dipole moment, polarizability, and first-order hyperpolarizability were computed to vindicate the non-linear optical (NLO) performance of the title compound. Gauss View, a graphical interface, was utilized to map and calculate the Molecular Electrostatic Potential (MEP). Natural Bond Orbital (NBO) estimates have also been performed, which furnish intelligence of hyperconjugation or redistribution of electron density. The charge distribution over the atoms through Mulliken's population analysis, and electronic properties such as HOMO-LUMO orbital, band gap energy, and chemical descriptors for the title compound were also determined.

Molecular docking

Molecular docking was carried out using AutoDock 4.2.6 software package, and PyMOL software to prepare the protein target and ligand [17,18]. The protein structure (PDB ID: 3QQL) was downloaded from the RCSB Protein Data Bank [19]. The molecular properties and pharmacokinetic prediction were performed using the online software molinspiration toolkit and Swiss ADME, respectively [20].

RESULTS AND DISCUSSIONS**Molecular Geometry**

The optimized molecular structure (Fig.1) and the associated geometrical parameters (Table 1) were quantified through the electron density-based quantum level computations and compared with the crystal structure of the reported structure; 2-(1,3-Benzoxazol-2-ylsulfanyl)-1-phenylethanone [13]. The calculated bond lengths and bond angles of the title compound are realized being in the range of: C-O= 1.3449-1.3526 [1.3704-1.389]; C=O = 1.2183 [1.212]; N-C = 1.3082-1.3604 [1.290-1.398]; C-S = 1.7621-1.762 [1.7043-1.8028]; C-C 1.4119-1.3773 [1.507- 1.374]; C-H = 1.08 [0.93] Å. The C-O-C and C-N-C bond angles are 108.17 [103.29] and 108.72°[103.67]°, respectively. The calculated values are found to be in the normal range and are in good agreement with the respective values of the similar reported structure [13].

Frontier Molecular Orbital (HOMO-LUMO) Analysis

Frontier Molecular Orbital (HOMO-LUMO) examination brings forth the intelligence of electron density, structure and conformation, electronic possessions, and chemical activity of the molecule. The global reactivity descriptors, the primary parameters were computed for the title molecule and listed in Table 1. The less band gap energy suggests that the chemical stability is low and chemical reactivity is high and the calculated values $\Delta E = -3.989$ eV and $\sigma = 0.1256$ specify the soft nature of the molecule. The HOMO-LUMO plot (Fig. 2) of the molecule, the ground state HOMO is localized whereas the first excited LUMO state is delocalized with contour surfaces. The estimated global chemical reactivity descriptors propounds that the title molecule exhibits significant electronic properties, i.e., chemically active.

CHARGE DISTRIBUTION ANALYSIS**Molecular Electrostatic Potential (MEP)**

Molecular electrostatic potential (MEP) is a visual tool that helps assess the molecular reactivity towards positively and negatively charged reactants via mapping of the molecular surface illustrating the three-dimensional charge distribution using a color-coded scheme. MEP surface investigation provides valuable information such as attractive (red) and repulsive (blue) potential regions, reactive sites, molecular size and shape, electrostatic potential values,





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and the structure-activity relationship [21]. In the color scheme adopted for the title molecule (Fig. 3), the red color around O14 and light red around N3 discloses the electron rich with a partial negative charge and slightly proton deficient regions, respectively. The maximum positive potential region around hydrogen atoms (electron donors) and maximum negative potential region around O14 (electron acceptor) expose the site for the nucleophilic and electrophilic attack, respectively.

Natural bond orbital (NBO) investigation

The second-order perturbation theory, an approximation method at the quantum level has been carried out to derive information regarding the delocalization of electron density within the molecule, donor-to-acceptor interaction energies due to second-order contacts between the filled and empty Lewis orbital, hyperconjugative intermolecular interactions, intra and intermolecular charge transfer (ICT), threshold occupancy of electrons, reduction in occupancy and energy of the system, etc.[22]. The stabilization energy $E(2)$ of the system and the computed associated parameters are listed in Table 3. The higher $E(2)$ and lower ΔE_{ij} values demonstrate the stronger charge transfer across the system and hence the stability of the system. The oxygen (O1) and sulfur (S10) atoms with lone pair act as donating group through $LP2-O1$, $LP2-S10$, $LP2-O1$ and $LP2-S10 \rightarrow \pi^*(C2-N3)$, $\pi^*(C2-N3)$, $\pi^*(C4-C5)$ and $\pi^*(C11-C12)$ with energies 34.26 ($\Delta E_{ij}=0.33$), 28.43 (0.25), 21.69 (0.37) and (20.35 (0.28) kcal/mol, respectively. The existence of $LP(O, S) \rightarrow \pi^*(C-C, C-N)$ and $\pi(C-C) \rightarrow \pi^*(C-C)$ explains the hyperconjugative $\pi \rightarrow \pi^*$ type charge transfer across donor to acceptor atoms [23]

Mulliken's atomic charges distribution analysis

Atomic charge distribution has a great influence on the quantum level estimations for molecular structures. The charge distribution analysis of the title molecule was obtained by Mulliken[24] population analysis using the B3LYP 6-311++G(d, p) method, which exposes the charges of every atom in the molecule [Table 4]. In the title molecule, the hydrogen atoms have positive charges, whereas the oxygen and sulphur atoms are with negative charges. This observation explains that the O atoms are lone paired and that charge transfer is initiated from oxygen to carbon. The resultant charges on C20 (-1.8230) – H31 (0.02242) and C19 (-0.3403) – H30 (0.1962) uncover the D...A charge transfer that defines the capability of hydrogen bond formation.

Local reactivity descriptors-Fukui function

The Fukui function is a local chemical reactivity descriptor that can be used for predetermining the reactivity of molecular elements, knowing about local descriptors of chemical reactivity and selectivity, and identifying the reactive regions and their modifications due to the addition of electrons. Based on the intelligence of Mulliken atomic charges of the neutral, cation, and anion states of the title molecule, Fukui functions (f^+ , f^- , f^0) are estimated [25] for nucleophilic, electrophilic, and radical strike, respectively. The natural population analysis at the r^{th} atomic site with the chemical species N (neutral), N+1 (anion), and N-1 (cation) has also been estimated. In this work, the atoms C2, C4, C5, C13, S10, and H21-H31 are more susceptible to nucleophilic strike while O1, O14, N3, C6, C9, C11, C12, and C15 - C20 atoms are susceptible to electrophilic strike which are found from the dual descriptors $\Delta f(r)$ [Table 5].

VIBRATIONAL ANALYSIS

The title compound is constituted of 31 atoms and hence has 87 normal modes of vibration. The theoretical calculations were done for a free molecule in a vacuum at B3LYP/6-311++G (d,p) level of theory, in addition to the experimental documentation of FT-IR and FT-Raman spectra for the sample. Fig. 4 displays the comparative representations of theoretical and experimental FT-IR and FT-Raman spectra, respectively. The Potential Energy Distribution (PED) is performed to derive the entire molecular motions present in the normal modes of vibrations of the title molecule. The vibrational modes are assigned with frequencies based on PED using the VEDA program [26]. The calculated vibrational frequencies at DFT levels have been scaled down by using the scaling factor 0.9613 [27] to minimize the difference between calculated and experimental data which arise due to the negligence of anharmonicity and electron density.





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FTIR VIBRATIONAL ASSIGNMENTS

In general, aromatic rings exhibit three different modes of vibration, namely stretching, in-plane bending, and out-of-plane bending vibrations in the respective regions. In this work, the experimental peaks at 3088 and 3094 in the FTIR spectrum are assigned to Ar.C-H stretching, while theoretically estimated signals in the band 3041–3082 (PED: 80–96%) are due to Ar.C-H stretching. The anticipated region for Ar. C- H in-plane bending is 1500-1000 cm^{-1} [28]. The recorded peaks at 1199, 1527, and 1580 cm^{-1} in FTIR spectrum are attributed to the pure C-C stretching, whereas the band extends from 1593- 990 cm^{-1} is assigned to the mixture of C-C stretching and HCC bending vibrations (Table 6). These allotments are in good agreement with the theoretically computed values (PED).

FT-RAMAN VIBRATIONAL ASSIGNMENTS

The comparative representation of experimentally recorded and theoretically computed FT-RAMAN spectra of the title material is displayed in Fig. 4. The peaks at 3037, 3049, 3056, and 3075 cm^{-1} are attributed to Ar. C-H stretching vibrations and are agreed well with the computed values in the wave number range 3041-3082 cm^{-1} (PED: 80–98%). The experimental peaks at 1558 and 1208 cm^{-1} are assigned to C-C stretching vibrations and are comparable with the calculated values of 1542 and 1207 cm^{-1} (60%). The recorded signals at 1500 and 1188 cm^{-1} are allocated to N-C stretching vibrations, which are in good agreement with the estimated values at 1488 and 1182 cm^{-1} (75%). The peak at 1654 of the FT-RAMAN spectrum is assigned to O-C stretching vibration and is comparable with the computed peak at 1647 cm^{-1} (75%). These allotments are in good agreement with the theoretically computed values [29].

Non- Linear Optical (NLO)property analysis

Investigation of nonlinear optical (NLO) effects in materials has gained momentum in the recent past because of their innumerable applications in photonics and optoelectronics. The relation between the molecular structure and the NLO property of the materials has been established through the characteristic parameters such as the total static dipole moment (μ), the mean polarizability (α), the anisotropy of the polarizability ($\Delta\alpha$), and the mean first-order hyperpolarizability (β), which were calculated using DFT-B3LYP level of theory with 6-311++G (d, p) basis set available in the Gaussian program package [30] and are expressed in electrostatic units (esu) using conversion factor of 0.1482×10^{-24} esu for α and 8.6393×10^{-33} esu for β [Table 7]. The first-order hyperpolarizability (β) was computed for the title molecule ($\beta = 13.281 \times 10^{-30}$ esu) with non-centrosymmetric space group C1 and compared with the reference material Urea ($\beta = 0.343272 \times 10^{-30}$ esu), from which it can be consolidated that the tested compound can be a potential candidate for nonlinear optical applications.

Quantum Theory Atoms In Molecule (QTAIM) - Topology analysis

Bader's Quantum Theory of Atoms in Molecules (QTAIM) has been used to explain the interactions between the atoms in covalent (single, double, and triple bonds) and non-covalent interactions such as van der Waals, $\pi \dots \pi$, X-H $\dots \pi$, hydrogen bonds, cation $\dots \pi$, and halogen bonds [31]. The concept of the bonding through bond paths (BP), bond critical points (BCPs), and the total electron energy density at the hydrogen bond critical point (HBCP) can be explained using the topological properties of ED and its derivatives [32,33]. There are four realizable values for CPs, they are (3, -3), (3, -1), (3, +1) and (3, +3). In the molecular graph [Fig. 5] the CP (3, +1) is found in the interior of the ring (yellow dot) including the one generated due to intra-molecular interaction (where electron density is minimum). While the CP (3, -1) provides an accumulation of electronic charge density along the atomic interaction line between the two nuclei that are bonded together (orange dot). The positive and small $\rho(\mathbf{r})$ and $\nabla^2 q(\mathbf{r})$ values (Table 8) disclose the weak and non-covalent interactions in the title molecule.

ELF and LOL investigation

The electron localization function (ELF) and localized orbital locator (LOL) have similar qualitative associations where ELF shows a relative localization for a spin-polarized system and has an explicit correlation with Fermi hole integration and LOL gives the actual kinetic energy term [32]. The colored gradient bond path interaction lines map along with color scale (0 to 1 for ELF and 0 to 0.800 for LOL) were obtained using the Multiwfn software program [34] is shown in Fig. 6. The strong (high) ELF around hydrogen atoms (red color) and weak ELF around carbon atoms (blue color) show the delocalized electron cloud in the range 0.5-1.0. Whereas, in the LOL molecular





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map, the white regions at the center of hydrogen atoms, the blue circle around carbon and sulfur atoms, and the red color between carbon-carbon, and carbon-sulfur atoms indicate the higher electron density region (> 0.8), the electron depletion region between valence and inner shells respectively.

Molecular Docking Studies

The thermodynamic properties corresponding to the best fit active site interaction are listed in Table 9 which indicates the strong binding between the ligand and the target [35]. The in-silico investigation (Fig.7) disclosed the possible non-covalent interactions including hydrogen bonds. The active site interaction between the ligand and co-crystal (Capecitabine) with the target protein (PDB ID: 3QQL) is shown in Fig.7a, b. The magnitude of active site binding affinity (binding energy), D...A distance, type of hydrogen bonds, amino acid residues and inhibition constant (K_i) are listed in Table 10. The estimated K_i value is in good agreement with the quantum of dose required to inhibit the proliferative activity [36]. The binding energy which is the measure of binding affinity and the stability of the compound remains higher (-6.56 kcal/mol.) than the co-crystal (-3.58 kcal/mol.) endorsing it as a potential candidate in the field of drug designing to act as an anticancer agent.

ADMET Analysis

The lipophilicity is a physicochemical property and plays a crucial role in quantifying ADMET molecular properties. In this work, ADMET properties (Table 11-13) including molecular weight ($MW < 500$), topological polar surface area (TPSA in the range 20-130 Å²), number of rotatable bonds ($RT < 10$), number of acceptor atoms ($HBA < 10$), donor atoms ($HBD < 5$) of the hydrogen bond, lipophilicity ($milogP < 5$; value lies between 1.35- 1.80 is ideal for good oral and intestinal absorption), and no violation of Lipinski rule of five (Ro5) illustrate that the material is 'drug-like' and empower us to estimate the bioavailability of the drug after oral administration [37,38]. Hence the title material is 'drug-like' and exhibits good bioavailability.

CONCLUSION

The GC-MS spectrum of the KabasuraKudineer (KSK) extract was recorded and investigated for the phytochemical constituents. Phytochemical (E)-3-(1, 3-benzoxazol-2-ylsulfanyl)-1-phenylprop-2-en-1-one (C1) was selected for DFT study employing B3LYP/6-311++G (d, p) basis set. Geometrical parameters for the optimized molecular structure were calculated and are found to be in good agreement with the literature values. The HOMO-LUMO analysis, MEP and NBO investigation revealed the positive potential and the negative potential sites for nucleophilic and electrophilic attack, respectively. The existence of $LP(O, S) \rightarrow \pi^*(C-C, C-N)$ and $\pi(C-C) \rightarrow \pi^*(C-C)$ suggest the hyperconjugative $\pi \rightarrow \pi^*$ type charge transfer across D-A atoms. Mulliken's charge analysis and Fukui functions calculations were also estimated. The vibrational modes are assigned with frequencies based on PED and the computed vibrational frequencies are compared with the experimental results. The first-order hyperpolarizability ($\beta = 13.281 \times 10^{-30}$ esu) of the title material of centrosymmetric space group C1 is compared with the reference material Urea ($\beta = 0.343272 \times 10^{-30}$ esu) and the compound can be a candidate for NLO applications. The positive and small topological properties of ED $q(r)$ and its derivatives $\nabla^2 q(r)$ disclosed the weak and non-covalent interactions in the title molecule. Based on the stability-defining interactions and binding energy (-6.56 kcal/mol.) as listed in the table the synthesized material can be endorsed as a potential candidate in the field of drug designing to act as an anticancer agent, which is supported by the results of ADMET investigation.

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Competing Interests

Authors have declared that no competing interests exist.





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Authors Contribution

K.Laavanya: Conceptualization, Writing-original draft. S.Muthu: Software, Validation, R. Yuvashri, and A. AnishFathima: Project administration; Resources, G. Usha: Validation, Writing – review & editing, Data curation, Supervision

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REFERENCES

1. Chakraborty, Indranil, and PrasenjitMaity, COVID-19 outbreak: Migration, effects on society, global environment and prevention, *Science of the total environment* 728 (2020) 138882.
2. COVID-19 and “Alternative” Treatments: What You Need To Know, <https://www.nccih.nih.gov/health/covid-19-and-alternative-treatments-what-you-need-to-know>
3. Paudyal, Vibhu, Shusen Sun, RabiaHussain, Mohammed H. Abutaleb, and Erick Wesley Hedima, Complementary and alternative medicines use in COVID-19: A global perspective on practice, policy and research, *Research in Social and Administrative Pharmacy* 18, no. 3 (2022) 2524-2528.
4. S. Natarajan, C. Anbarasi, P. Sathiyarajeswaran, P. Manickam, S. Geetha, R. Kathiravan, P. Prathiba et al., KabasuraKudineer (KSK), a poly-herbal Siddha medicine, reduced SARS-CoV-2 viral load in asymptomatic COVID-19 individuals as compared to vitamin C and zinc supplementation: findings from a prospective, exploratory, open-labeled, comparative, randomized controlled trial, Tamil Nadu, India, *Trials* 22, no. 1 (2021) 1-11.
5. Nisha, M. Afrin, S. Preetha, J. Selvaraj, and G. Sridevi. , Effect of KabasuraKudineer Extract on Inflammatory Cytokines [Interleukin-6 and Tumour Necrosis Factor- α] in Lung Cancer Cell Line A549., *Journal of Pharmaceutical Research International* 33, no. 47B (2021) 653-660.
6. Rammohan, Aluru, JulakantiSatyanarayana Reddy, GundalaSrivaya, ChittluriNarasimhaRao, and Grigory V. Zyryanov, Chalcone synthesis, properties and medicinal applications: a review, *Environmental Chemistry Letters* 18 (2020) 433-458.
7. Owaba, A. D. C., O. Miediegha, and R. R. Oladiran, Chalcones as Sythons for Heterocyclic Compounds-A Review, *Int. J. Curr. Res* 12 (2020): 13672-13681.
8. Vásquez-Martínez, Yesseny A., Mauricio E. Osorio, Diego A. San Martín, Marcela A. Carvajal, Alejandra P. Vergara, Elizabeth Sanchez, Marcela Raimondi et al. ,Antimicrobial, anti-inflammatory and antioxidant activities of polyoxygenatedchalcones, *Journal of the Brazilian Chemical Society* 30 (2019) 286-304.
9. Yazdan, ShaikKhadar, D. VidyaSagar, and AfzalBashaShaik., Chemical and Biological Potentials of Chalcones A Review, *Organic & Medicinal Chemistry International Journal* 1, no. 1 (2015) 20-28.
10. Silva, Marianna C., Vitor S. Duarte, Jean MF Custodio, Jaqueline E. Queiroz, Gilberto LB de Aquino, Allen G. Oliver, and Hamilton B. Napolitano. ,Comparative conformational study of a new terpenoid-like chalcone., *Journal of Molecular Structure* 1228 (2021) 129743.
11. Ibaouf, K. H., R. K. Hussein, H. M. Elkhair, and A. O. Elzupir., Experimental and theoretical study of the structure, frontier molecular orbital, tautomerism and spectral analysis of 3-(p-substituted phenyl)-5-phenyl-1H-pyrazole, *Journal of Molecular Liquids* 287 (2019) 110675.
12. Skoog, Douglas A., Donald M. West, F. James Holler, and Stanley R. Crouch, *Fundamentals of analytical chemistry*, Cengage learning, 2013.
13. HosseinLoghmani-Khouzani, DariushHajihaidari, Ward T. Robinson, Noorsaadah Abdul Rahman and Reza Kia, 2-(1,3-Benzoxazol-2-ylsulfanyl)-1-phenylethanone, *ActaCryst.* (2009). E65, o2287.
14. Laavanya, K., B. Manju, D. Angeline Shirmila, M. Krishna Priya, J. Hemalatha, and G. Usha., GC-MS and optical characterization, biological property studies of ethanolic extract of kabasurakudineer and molecular docking





Laavanya et al.,

- investigation of (e)-3-phenyl-1-(2, 2, 4-trimethylquinolin-1-yl) prop-2-en-1-one, *Rasayan Journal of Chemistry* 16, no. 2 (2023).
15. Frisch, M. J., G. W. Trucks, H. B. Schlegel, G. E. Scuseria, M. A. Robb, J. R. Cheeseman, J. A. Montgomery Jr et al., *Gaussian 03, Revisions D. 02*. Gaussian, Inc.: Wallingford, Conn., USA (2004).
 16. Becke, A. D., *Density-functional thermochemistry III the role of exact exchange*. *J. Chem. Phys.* 1993, 98,5648-5652,
 17. Morris, Garrett M., David S. Goodsell, Robert S. Halliday, Ruth Huey, William E. Hart, Richard K. Belew, and Arthur J. Olson, *Automated docking using a Lamarckian genetic algorithm and an empirical binding free energy function*, *Journal of computational chemistry* 19, no. 14 (1998) 1639-1662.
 18. Schrodinger, L. L. C., *The PyMOL molecular graphics system*, Version 1 (2015) 8.
 19. Subramanian, Gomathy, FarhathSherin, NainaMerin Joy, Ashish D. Wadhvani, GowrammaByran, and A. Shanish Antony, *Docking studies and synthesis of novel 4-thiazolidinone derivatives bearing 1, 3, 4-oxadiazole moiety as sirt-3 activators targeting parkinson's disease*, *Rasayan Journal of Chemistry* 15, no. 1 (2022).
 20. Eugene N Muratov , RommieAmaro, Carolina H Andrade, Nathan Brown, Sean Ekins, Denis Fourches, *A critical overview of computational approaches employed for COVID-19 drug discovery* ,*Chem.Soc Rev*,2021 Aug 21;50(16) 9121-9151.
 21. Weinhold, Frank, and Clark R. Landis, *Natural bond orbitals and extensions of localized bonding concepts*, *Chemistry Education Research and Practice* 2, no. 2 (2001) 91-104.
 22. Sebastian, S., S. Sylvestre, J. Jayabharathi, S. Ayyapan, M. Amalanathan, K. Oudayakumar, and Ignatius A. Herman. *Study on conformational stability, molecular structure, vibrational spectra, NBO, TD-DFT, HOMO and LUMO analysis of 3, 5-dinitrosalicylic acid by DFT techniques.*, *SpectrochimicaActa Part A: Molecular and Biomolecular Spectroscopy* 136 (2015) 1107-1118.
 23. Vasić, Jelena, DušanDimić, Marko Antonijević, Edina H. Avdović, DejanMilenković, ĐuraNakarada, JasminaDimitrićMarković et al., *The electronic effects of 3-methoxycarbonylcoumarin substituents on spectral, antioxidant, and protein binding properties*, *International journal of molecular sciences* 24, no. 14 (2023) 11820.
 24. Fukui, Kenichi, TeijiroYonezawa, and HaruoShingu, *A molecular orbital theory of reactivity in aromatic hydrocarbons*, *The Journal of Chemical Physics* 20, no. 4 (1952) 722-725.
 25. Anju, L. S., D. Arulhas, I. Hubert Joe, and S. Balachandran, *Density functional theory, spectroscopic and hydrogen bonding analysis of fenoxycarb–water complexes*, *Journal of Molecular Structure* 1201 (2020) 127201.
 26. Jamróz, Michał H., *Vibrational energy distribution analysis (VEDA): scopes and limitations*, *SpectrochimicaActa Part A: Molecular and Biomolecular Spectroscopy* 114 (2013) 220-230.
 27. Scott, Anthony P., and Leo Radom, *Harmonic vibrational frequencies: an evaluation of Hartree– Fock, Møller– Plesset, quadratic configuration interaction, density functional theory, and semiempirical scale factors*, *The Journal of Physical Chemistry* 100, no. 41 (1996) 16502-16513.
 28. Karabacak, Mehmet, Mustafa Kurt, and AhmetAtac, *Experimental and theoretical FT-IR and FT-Raman spectroscopic analysis of N1-methyl-2-chloroaniline*, *Journal of Physical Organic Chemistry* 22, no. 4 (2009) 321-330.
 29. Shobana, D., S. Sudha, D. Dimić, and D. Ramarajan, *Synthesis, structural and spectral investigations of an optically active EN'-(3, 4-dimethoxybenzylidene)- 4-fluorobenzohydrazide crystal*, *Vibrational Spectroscopy* 126 (2023) 103541.
 30. Kuruvilla, Tintu K., Johanan Christian Prasana, S. Muthu, Jacob George, and Sheril Ann Mathew., *Quantum mechanical and spectroscopic (FT-IR, FT-Raman) study, NBO analysis, HOMO-LUMO, first order hyperpolarizability and molecular docking study of methyl [(3R)-3-(2-methylphenoxy)-3-phenylpropyl] amine by density functional method*, *SpectrochimicaActa Part A: Molecular and Biomolecular Spectroscopy* 188 (2018) 382-393.
 31. Abraham, Jose P., D. Sajan, VenkatarayaShettigar, S. M. Dharmaprakash, I. Němec, I. Hubert Joe, and V. S. Jayakumar, *Efficient π -electron conjugated push–pull nonlinear optical chromophore 1-(4-methoxyphenyl)-3-(3, 4-dimethoxyphenyl)-2-propen-1-one: A vibrational spectral study*, *Journal of Molecular Structure* 917, no. 1 (2009) 27-36.





Laavanya et al.,

32. Parthasarathi, R., V. Subramanian, and N. Sathyamurthy, Hydrogen bonding in phenol, water, and phenol-water clusters, *The Journal of Physical Chemistry A* 109, no. 5 (2005) 843-850.
33. Arputharaj, David Stephen, Venkatesha R. Hathwar, Tayur N. Guru Row, and PoomaniKumaradhas., Topological electron density analysis and electrostatic properties of aspirin: an experimental and theoretical study, *Crystal growth & design* 12, no. 9 (2012) 4357-4366.
34. Lu, Tian, and Feiwu Chen., Multiwfn: A multifunctional wavefunction analyzer, *Journal of computational chemistry* 33, no. 5 (2012) 580-592.
35. Göller, Andreas H., Lara Kuhnke, FlorianeMontanari, Anne Bonin, Sebastian Schneckener, Antonius TerLaak, JörgWichard, Mario Lobell, and Alexander Hillisch, Bayer's in silico ADMET platform: A journey of machine learning over the past two decades, *Drug Discovery Today* 25, no. 9 (2020) 1702-1709.
36. Ferreira, Leonardo LG, and Adriano D. Andricopulo, ADMET modeling approaches in drug discovery, *Drug discovery today* 24, no. 5 (2019) 1157-1165.
37. Katz, Daniel, Kate Fike, Justin Longenberger, Steve Placko, Laurence Philippe-Venec, and Andrew Chervenak, AlphaLogD determination: An optimized reversed-phase liquid chromatography method to measure lipophilicity on neutral and basic small and Beyond-Rule-of-Five compounds, *Journal of Chromatography A* 1674 (2022) 463146.
38. Benet, L.Z.; Hosey, C.M.; Tudor, O.U.; Oprea, I., BDDCS, the Rule of 5 and drugability, *Advanced Drug Delivery Reviews* 101 (2016), 89–98.

Table 1. Geometric parameters of C1 and reference compound using DFT/B3LYP/6-311++G (d, p) level of theory

a) Bond lengths [Å]

Title compound C1				Reference compound			
Atoms	Bond distance	Atoms	Bond distance	Atoms	Bond distance	Atoms	Bond distance
O1-C2	1.34	C11-H25	1.08	S1-C7	1.7343	C8-C9	1.507
O1-C5	1.35	C12-C13	1.4119	S1-C8	1.8028	C8-H8	0.9700
C2-N3	1.3082	C12-H26	1.0801	O1-C7	1.3704	C8-H8	0.9700
C2-S10	1.7621	C13-O14	1.2183	O1-C1	1.389	C9-O2	1.212
N3-C4	1.3604	C13-C15	1.48	N1-C7	1.290	C9-C10	1.489
C4-C5	1.4032	C15-C16	1.3955	N1-C6	1.398	C10-C15	1.393
C4-C9	1.396	C15-C20	1.3956	C1-C2	1.374	C10-C11	1.397
C5-C6	1.3856	C16-C17	1.3796	C1-C6	1.389	C11-C2	1.381
C6-C7	1.3801	C16-H27	1.08	C2-C3	1.387	C11-H11	0.9300
C6-H21	1.0799	C17-C18	1.3836	C2-H2	0.9300	C12-C13	1.385
C7-C8	1.3867	C17-H28	1.08	C3-C4	1.394	C12-H12	0.9300
C7-H22	1.08	C18-C19	1.3836	C3-H3	0.9300	C13-C14	1.383
C8-C9	1.3773	C18-H29	1.08	C4-C5	1.389	C13-H13	0.9300
C8-H23	1.08	C19-C20	1.3795	C4-H4	0.9300	C14-C15	1.386
C9-H24	1.08	C19-H30	1.0801	C5-C6	1.383	C14-H14	0.9300
S10-C11	1.762	C20-H31	1.08	C5-H5	0.9300	C15-H15	0.9300
C11-C12	1.3527						

b) Bond Angle [°]

Title compound C1				Reference compound			
Atoms	Angle	Atoms	Angle	Atoms	Angle	Atoms	Angle
C2-O1-C5	108.17	C12-C11-H25	120.00	C7-S1-C8	95.81	S1-C8-H8	109.7
O1-C2-N3	110.08	C11-C12-C13	120.00	C7-O1-C1	103.29	C9-C8-H8	109.7
O1-C2-S10	124.96	C11-C12-H26	119.99	C7-N1-C6	103.67	S1-C8-H8	109.7
N3-C2-S10	124.95	C13-C12-H26	119.99	C2-C1-O1	128.62	H8A-C8-H8	108.2





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C ₂ -N ₃ -C ₄	108.72	C ₁₂ -C ₁₃ -O ₁₄	119.99	C ₂ -C ₁ -C ₆	124.18	O ₂ -C ₉ -C ₁₀	122.17
N ₃ -C ₄ -C ₅	106.64	C ₁₂ -C ₁₃ -C ₁₅	120.00	O ₁ -C ₁ -C ₆	107.20	O ₂ -C ₉ -C ₈	120.60
N ₃ -C ₄ -C ₉	133.68	O ₁₄ -C ₁₃ -C ₁₅	119.99	C ₁ -C ₂ -C ₃	115.13	C ₁₀ -C ₉ -C ₈	117.23
C ₅ -C ₄ -C ₉	119.67	C ₁₃ -C ₁₅ -C ₁₆	120.14	C ₁ -C ₂ -H ₂	122.4	C ₁₅ -C ₁₀ -C ₁₁	119.18
O ₁ -C ₅ -C ₄	106.39	C ₁₃ -C ₁₅ -C ₂₀	120.13	C ₃ -C ₂ -H ₂	122.4	C ₁₅ -C ₁₀ -C ₉	122.08
O ₁ -C ₅ -C ₆	133.78	C ₁₆ -C ₁₅ -C ₂₀	119.72	C ₂ -C ₃ -C ₄	122.13	C ₁₁ -C ₁₀ -C ₉	118.74
C ₄ -C ₅ -C ₆	119.83	C ₁₅ -C ₁₆ -C ₁₇	119.85	C ₂ -C ₃ -H ₃	118.9	C ₁₂ -C ₁₁ -C ₁₀	120.30
C ₅ -C ₆ -C ₇	119.89	C ₁₅ -C ₁₆ -H ₂₇	120.06	C ₄ -C ₃ -H ₃	118.9	C ₁₂ -C ₁₁ -H ₁₁	119.8
C ₅ -C ₆ -H ₂₁	120.06	C ₁₇ -C ₁₆ -H ₂₇	120.07	C ₅ -C ₄ -C ₃	121.36	C ₁₀ -C ₁₁ -H ₁₁	119.9
C ₇ -C ₆ -H ₂₁	120.05	C ₁₆ -C ₁₇ -C ₁₈	120.14	C ₅ -C ₄ -H ₄	119.3	C ₁₁ -C ₁₂ -C ₁₃	120.01
C ₆ -C ₇ -C ₈	120.47	C ₁₆ -C ₁₇ -H ₂₈	119.92	C ₃ -C ₄ -H ₄	119.3	C ₁₁ -C ₁₂ -H ₁₂	120.0
C ₆ -C ₇ -H ₂₂	119.77	C ₁₈ -C ₁₇ -H ₂₈	119.93	C ₆ -C ₅ -C ₄	117.13	C ₁₃ -C ₁₂ -H ₁₂	120.0
C ₈ -C ₇ -H ₂₂	119.76	C ₁₇ -C ₁₈ -C ₁₉	120.28	C ₆ -C ₅ -H ₅	121.4	C ₁₄ -C ₁₃ -C ₁₂	120.29
C ₇ -C ₈ -C ₉	120.40	C ₁₇ -C ₁₈ -H ₂₉	119.85	C ₄ -C ₅ -H ₅	121.4	C ₁₄ -C ₁₃ -H ₁₃	119.9
C ₇ -C ₈ -H ₂₃	119.80	C ₁₉ -C ₁₈ -H ₂₉	119.86	C ₅ -C ₆ -C ₁	120.06	C ₁₂ -C ₁₃ -H ₁	119.9
C ₉ -C ₈ -H ₂₃	119.80	C ₁₈ -C ₁₉ -C ₂₀	120.14	C ₅ -C ₆ -N ₁	130.61	C ₁₃ -C ₁₄ -C ₁₅	119.98
C ₄ -C ₉ -C ₈	119.73	C ₁₈ -C ₁₉ -H ₃₀	119.92	C ₁ -C ₆ -N ₁	109.33	C ₁₃ -C ₁₄ -H ₁₄	120.0
C ₄ -C ₉ -H ₂₄	120.13	C ₂₀ -C ₁₉ -H ₃₀	119.92	N ₁ -C ₇ -O ₁	116.50	C ₁₅ -C ₁₄ -H ₁₄	120.0
C ₈ -C ₉ -H ₂₄	120.15	C ₁₅ -C ₂₀ -C ₁₉	119.84	N ₁ -C ₇ -S ₁	128.59	C ₁₄ -C ₁₅ -C ₁₀	120.25
C ₂ -S ₁₀ -C ₁₁	100.00	C ₁₅ -C ₂₀ -H ₃₁	120.07	O ₁ -C ₇ -S ₁	114.90	C ₁₄ -C ₁₅ -H ₁₅	119.9
S ₁₀ -C ₁₁ -C ₁₂	119.99	C ₁₉ -C ₂₀ -H ₃₁	120.07	C ₉ -C ₈ -S ₁	109.67	C ₁₀ -C ₁₅ -H ₁	119.9
S ₁₀ -C ₁₁ -H ₂₅	119.99			C ₉ -C ₈ -H ₈	109.7		

Table 2. Calculated global reactivity descriptors

Parameters	Computed Values
HOMO energy	-6.446 eV
LUMO energy	-2.457 eV
HOMO-LUMO energy gap	-3.989 eV
Ionization Potential	+6.446
Electron Affinity	+2.457
Electro-negativity	4.45
Chemical Potential	-4.45
Chemical Hardness	3.989
Chemical Softness	0.1256
Electrophilicity Index	2.4821

Table 3. Second order perturbation theory based computation of Fock-matrix on NBO of the title molecule

	Donor Type	ED/e	Acceptor Type	ED/e	E(2) kcal/mol	E(j)-E(i) a.u.	F(i,j) a.u.
1	$\pi(C_2-N_3)$	1.90355					
			$\pi^*(C_4-C_5)$	0.447	14.15	0.36	0.07
2	$\pi(C_4-C_5)$	1.61997	$\pi^*(C_2-N_3)$	0.34318	11.9	0.25	0.049
			$\pi^*(C_6-C_7)$	0.34325	18.89	0.29	0.067
			$\pi^*(C_8-C_9)$	0.31613	17.75	0.3	0.066
3	$\pi(C_6-C_7)$	1.69514	$\pi^*(C_4-C_5)$	0.447	21.8	0.27	0.071
			$\pi^*(C_8-C_9)$	0.31613	18.75	0.29	0.066
4	$\pi(C_8-C_9)$	1.69442	$\pi^*(C_4-C_5)$	0.447	20.42	0.27	0.069
			$\pi^*(C_6-C_7)$	0.34325	20.35	0.28	0.068





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5	$\pi(C_{11}-C_{12})$	1.892	$\pi^*(C_{13}-O_{14})$	0.2051	17.68	0.32	0.068
6	$\pi(C_{15}-C_{20})$	1.63918	$\pi^*(C_{13}-O_{14})$	0.2051	18.49	0.27	0.066
			$\pi^*(C_{16}-C_{17})$	0.28246	19.42	0.29	0.068
			$\pi^*(C_{18}-C_{19})$	0.32066	18.8	0.28	0.066
7	$\pi(C_{16}-C_{17})$	1.65063	$\pi^*(C_{15}-C_{20})$	0.36922	19.33	0.28	0.066
			$\pi^*(C_{18}-C_{19})$	0.32066	21.81	0.28	0.07
8	$\pi(C_{18}-C_{19})$	1.65076	$\pi^*(C_{15}-C_{20})$	0.36922	21.58	0.28	0.07
			$\pi^*(C_{16}-C_{17})$	0.28246	17.59	0.29	0.065
9	LP(2) - O ₁	1.74188	$\pi^*(C_2-N_3)$	0.34318	34.26	0.33	0.098
			$\pi^*(C_4-C_5)$	0.447	21.69	0.37	0.084
10	LP(1) - N ₃	1.9046	$\sigma^*(O_1-C_2)$	0.06605	13.37	0.69	0.086
11	LP(2) - S ₁₀	1.72958	$\pi^*(C_2-N_3)$	0.34318	28.43	0.25	0.076
			$\pi^*(C_{11}-C_{12})$	0.13694	20.35	0.28	0.07
12	LP(2) - O ₁₄	1.88476	$\sigma^*(C_{12}-C_{13})$	0.06211	19.6	0.68	0.105
			$\sigma^*(C_{13}-C_{15})$	0.06546	18.82	0.69	0.103

Table.4 Mulliken’s atomic charges analysis

Atoms	Charges	Atoms	Charges
1 O	-0.056459	17 C	-0.411190
2 C	0.373675	18 C	-0.339424
3 N	0.038047	19 C	-0.340445
4 C	0.271624	20 C	-1.829883
5 C	0.891694	21 H	0.185964
6 C	-0.636884	22 H	0.161876
7 C	-0.411407	23 H	0.171604
8 C	-0.176640	24 H	0.178841
9 C	-0.486494	25 H	0.368372
10 S	-0.280430	26 H	0.105525
11 C	0.009589	27 H	0.198209
12 C	0.048761	28 H	0.174286
13 C	-0.739651	29 H	0.151674
14 O	-0.252793	30 H	0.196234
15 C	1.494249	31 H	0.024228
16 C	0.917245		

Table 5: Local reactivity descriptors estimated via Fukui functions

Atoms	Mulliken atomic charges			Fukui functions (NPA)			Local softness (NPA)			Dual descriptor $\Delta f(r)$ (NPA)
	N (0,1)	N +1 (-1, 2)	N-1 (1,2)	f_r^+	f_r^-	f_r^0	$s_r^+ f_r^+$	$s_r^- f_r^-$	$s_r^0 f_r^0$	
O1	-0.4823	-0.2457	-0.2334	0.2365	0.2489	0.0062	0.0297	0.0313	0.0008	-0.2365
C2	0.3832	0.2162	0.1876	-0.1670	-0.1956	-0.0143	-0.0210	-0.0246	-0.0018	0.1670
N3	-0.5084	-0.2601	-0.1723	0.2484	0.3361	0.0439	0.0312	0.0422	0.0055	-0.2484
C4	0.0896	0.0484	0.1095	-0.0412	0.0199	0.0305	-0.0052	0.0025	0.0038	0.0412





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C5	0.2729	0.1332	0.2128	-0.1397	-0.0601	0.0398	-0.0175	-0.0075	0.0050	0.1397
C6	-0.2375	-0.1193	-0.1409	0.1182	0.0966	-0.0108	0.0148	0.0121	-0.0014	-0.1182
C7	-0.1967	-0.1058	0.0414	0.0909	0.2381	0.0736	0.0114	0.0299	0.0092	-0.0909
C8	-0.2059	-0.1125	-0.0798	0.0934	0.1261	0.0164	0.0117	0.0158	0.0021	-0.0934
C9	-0.1939	-0.0947	-0.0644	0.0992	0.1295	0.0152	0.0125	0.0163	0.0019	-0.0992
S10	0.3744	0.1564	0.4589	-0.2181	0.0845	0.1513	-0.0274	0.0106	0.0190	0.2181
C11	-0.2694	-0.0820	-0.1655	0.1874	0.1039	-0.0417	0.0235	0.0130	-0.0052	-0.1874
C12	-0.3074	-0.1526	0.0018	0.1548	0.3092	0.0772	0.0194	0.0388	0.0097	-0.1548
C13	0.5129	0.2799	0.2371	-0.2330	-0.2757	-0.0214	-0.0293	-0.0346	-0.0027	0.2330
O14	-0.5703	-0.2470	-0.2483	0.3233	0.3219	-0.0007	0.0406	0.0404	-0.0001	-0.3233
C15	-0.1359	-0.0534	-0.0604	0.0825	0.0754	-0.0035	0.0104	0.0095	-0.0004	-0.0825
C16	-0.1496	-0.0555	-0.0761	0.0941	0.0734	-0.0103	0.0118	0.0092	-0.0013	-0.0941
C17	-0.2011	-0.1247	-0.0614	0.0765	0.1397	0.0316	0.0096	0.0175	0.0040	-0.0765
C18	-0.1763	-0.0740	-0.0627	0.1024	0.1137	0.0056	0.0129	0.0143	0.0007	-0.1024
C19	-0.2053	-0.1210	-0.1010	0.0843	0.1044	0.0100	0.0106	0.0131	0.0013	-0.0843
C20	-0.1710	-0.0765	-0.0533	0.0945	0.1177	0.0116	0.0119	0.0148	0.0015	-0.0945
H21	0.2234	0.1048	0.1250	-0.1187	-0.0984	0.0101	-0.0149	-0.0124	0.0013	0.1187
H22	0.2088	0.0965	0.1136	-0.1123	-0.0952	0.0085	-0.0141	-0.0120	0.0011	0.1123
H23	0.2090	0.0973	0.1170	-0.1117	-0.0919	0.0099	-0.0140	-0.0115	0.0012	0.1117
H24	0.2206	0.1054	0.1215	-0.1152	-0.0990	0.0081	-0.0145	-0.0124	0.0010	0.1152
H25	0.2621	0.1226	0.1379	-0.1396	-0.1242	0.0077	-0.0175	-0.0156	0.0010	0.1396
H26	0.1993	0.0871	0.1050	-0.1121	-0.0943	0.0089	-0.0141	-0.0118	0.0011	0.1121
H27	0.2319	0.1094	0.1196	-0.1225	-0.1123	0.0051	-0.0154	-0.0141	0.0006	0.1225
H28	0.2082	0.0925	0.1107	-0.1158	-0.0975	0.0091	-0.0145	-0.0122	0.0011	0.1158
H29	0.2067	0.0893	0.1107	-0.1174	-0.0959	0.0107	-0.0147	-0.0121	0.0013	0.1174
H30	0.2071	0.0919	0.1107	-0.1152	-0.0964	0.0094	-0.0145	-0.0121	0.0012	0.1152
H31	0.2011	0.0939	0.0988	-0.1072	-0.1023	0.0024	-0.0135	-0.0129	0.0003	0.1072

Table 6. Computed and experimental vibrational frequencies assignment for the title molecule based on PED percentage

Mode	Experimental Wavenumbers cm^{-1}		B3LYP/ 6311++G (d,p)				Assignments (PED)
	FTIR	FT - Raman	Theoretical Wavenumbers				
			Unscaled Value	Scaled Value	IR Intensity	Raman Intensity	
87	3094	-	3207	3082	2	7	YCH (88)
86	3088	-	3206	3081	1	12	YCH (80)
85	-	3075	3202	3077	2	4	YCH (89)
84	-	-	3202	3077	1	3	YCH (92)
83	-	-	3190	3066	2	4	YCH (87)
82	-	-	3187	3063	2	9	YCH (98)





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81	-	-	3184	3060	3	7	YCH (91)
80	-	3056	3182	3058	3	1	YCH (96)
79	-	-	3175	3051	2	7	YCH (93)
78	-	3049	3173	3050	1	3	YCH (93)
77	-	3037	3164	3041	0	2	YCH (94)
76	-	1654	1714	1647	30	6	YOC (75)
75	1593	1589	1653	1588	0	6	YCC (38)+βHCC(10)
74	1580	1584	1640	1576	2	2	YCC (59)
73	-	-	1637	1574	14	12	YCC (61)+βHCC(19)
72	1554	1558	1617	1554	13	4	YCC (39)+βHCC(19)
71	1527	1539	1604	1542	100	100	YCC (60)
70	1481	1500	1548	1488	55	30	YNC (75)
69	1462	1462	1521	1462	0	3	βHCC(62)+YCC (24)
68	1449	1443	1505	1446	1	0	βHCC(49)+YCC (16)
67	1429	1424	1476	1419	9	3	βHCC(52)+YCC (12)
66	1416	1411	1476	1418	9	7	βHCC(53)+YCC (13)
65	1331	1335	1375	1322	2	3	YCC (63)+βHCC(14)
64	1305	1309	1367	1313	10	4	βHCC(37)+YCC (26)
63	1291	1297	1345	1292	8	1	YCC (67)+βHCC(11)
62	1265	1271	1321	1269	4	2	βHCC(49)+YCC (16)
61	1245	1252	1308	1257	0	1	βHCC(69)+YCC (11)
60	1213	1220	1262	1213	43	1	βHCS(28)+YCC (20)
59	1199	1208	1256	1207	39	20	YCC (65)
58	1174	1188	1230	1182	15	1	YNC (51)
57	1160	1169	1208	1161	11	6	βHCS(53)+YCC (12)
56	1147	1150	1204	1157	10	1	βHCC(74)+YCC (21)
55	1134	1131	1183	1137	1	0	βHCC(77)
54	1128	1124	1171	1125	0	2	βHCC(71)+YCC (20)
53	1107	1105	1148	1104	47	5	YCC (41)+βHCC(17)
52	-	1061	1113	1070	20	1	YCC (52)+βHCC(16)
51	1075	1054	1108	1065	1	0	YCC (48)+βHCC(18)
50	1016	1016	1052	1011	1	1	YCC (80)+βHCC(24)
49	996	997	1029	989	28	3	YCC (46)+βHCC(24)
48	990	984	1024	984	2	2	YCC (67)+βHCC(14)
47	970	965	1017	977	0	0	τ CCCH(93)
46	-	-	1016	977	0	4	βHCC(56)+YCC (39)
45	964	959	996	958	1	0	τ CCCH(87)
44	950	946	988	950	8	0	τ HCSC(80)
43	937	940	979	941	0	0	τ CCHH(93)





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42	918	914	951	914	1	0	β CCO(48)+YSC (16)
41	904	901	945	908	1	0	τ CCOH(91)
40	-	-	944	908	0	0	τ CCCH(87)
39	878	875	906	871	6	1	β CCH(61)
38	852	850	891	857	7	3	β CCH(46)
37	832	831	860	827	0	0	τ CCCH(84)
36	826	825	858	825	0	0	τ CCOH(88)
35	-	818	851	818	1	0	τ CCCH(84)
34	793	793	823	791	2	1	YCC (77)
33	767	761	782	751	5	0	τ HCSC(85)
32	754	748	779	749	23	4	YCC (54)
31	734	729	759	729	19	0	τ CCOH(94)
30	708	691	725	697	0	0	τ CCOH(87)
29	675	678	701	674	9	0	τ CCCH(89)
28	662	652	686	659	4	0	τ HCSC(77)
27	636	633	670	644	1	0	τ HCSC(81)
26	629	640	666	640	18	0	β CCH(66)
25	597	-	635	611	0	0	β HCC(73)+YCC (10)
24	609	608	632	607	0	0	β CCC(88)
23	570	582	608	584	1	1	β HCC(54)+YSC (15)
22	557	551	580	558	0	0	τ CCCH(97)
21	511	513	531	510	0	3	β CCS(78)
20	472	-	481	462	0	1	β CCO(74)
19	433	-	449	432	0	0	τ CCOH(76)
18	413	-	435	418	0	0	β HCS(14)+YSC (12)+ β HCC(11)
17	-	-	434	417	1	0	τ CCCH(89)
16	-	-	411	395	0	0	τ CCCH(98)
15	-	-	373	359	0	0	YSC (22)+ β HCC(15)
14	-	-	316	303	3	1	β HCS(72)
13	-	-	304	292	0	0	τ CCOH(80)
12	-	-	254	244	1	0	β HCS(52)+ β CCO(14)
11	-	-	252	242	0	0	τ CCCH(79)+ τ CSCO(11)
10	-	-	190	183	0	0	τ CCCH(85)
9	-	-	178	171	0	0	β CCO(47)
8	-	-	174	167	0	0	τ CCOH(76)
7	-	-	112	108	0	0	τ CCHS(82)
6	-	-	104	100	0	0	β CCS(72)
5	-	-	81	78	0	0	τ CCHS(59)+ τ CCOH(17)
4	-	-	35	33	0	0	β HCS(80)





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3		-	24	23	0	0	τ CCOS(74)
2	-	-	12	11	0	0	τ CCCS(48)+ τ CCOH(24) τ CCHS(14)

Table 7. The values of calculated dipole moment μ (D), polarizability (α), and first order hyperpolarizability (β) of the title molecule using B3LYP/6-311++G (d, p) basis set

Parameters	B3LYP/6-311++G(d,p)	Parameters	B3LYP/6-311++G(d,p)
μ_x	0.025055	β_{xxx}	-854.171432
μ_y	-0.9315766	β_{xyy}	1231.876823
μ_z	-0.0000384	β_{xyy}	-111.900601
μ (D)	0.931913	β_{yyy}	11.9922156
α_{xx}	417.6114859	β_{zxx}	-0.8977969
α_{xy}	11.7779523	β_{xyz}	0.247929
α_{yy}	212.7908743	β_{zyy}	-0.0673012
α_{xz}	-0.0092172	β_{xzz}	24.4685462
α_{yz}	0.0017112	β_{yzz}	-28.7423426
α_{zz}	111.9292724	β_{zzz}	-0.0435879
α (e.s.u)	3.6671×10^{-23}	β_{tot} (e.s.u)	13.281×10^{-30}
$\Delta \alpha$ (e.s.u)	1.1441×10^{-22}		

Table 8. Topological parameters of the title molecule (C1)

Interactions	$\rho(r)$	$\nabla^2 \rho(r)$	H(r)	G(r)	V(r)	λ_1	λ_2	λ_3	$E_{bond} \text{ kJ.mol}^{-1}$	ELF	LOL
C12-H26...H31	0.0127	0.0465	0.0022	0.0094	-0.0071	-0.1815	-0.1815	-0.1815	0.0022	0.0429	0.1794

Table 9. The thermodynamic properties for best docking conformation of the title molecule (C1)

Interaction	ΔG_{bind} (kJ/mol.)	$\Delta G_{vdW+Hbond+desol.}$ (kJ/mol.)	$\Delta G_{elec.}$ (kJ/mol.)	$\Delta G_{tot.}$ (kJ/mol.)	$\Delta G_{tor.}$ (kJ/mol.)	$\Delta G_{unbo.}$ (kJ/mol.)
Ligand-Receptor	-32.426	-32.258	-0.1674	-3.138	4.979	-3.891

Table 10. Molecular docking analysis for title molecule (C1)

Target protein	Ligand	Binding Site Interaction	D-H...A (Å)	Binding energy (kcal/mol)	Estimated inhibition constant (μM)





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3QQL	Ligand (C1)	LEU83(N-H...O)	2.0	-6.56	15.5
	Capecitabine (Co-crystal)	GLU12(N-H...O)	2.1	-3.58	23.80
		LYS33(N-H...O)	2.5		
		LYS33(N-H...O)	2.4		

Table 11 : Drug-likeness Score

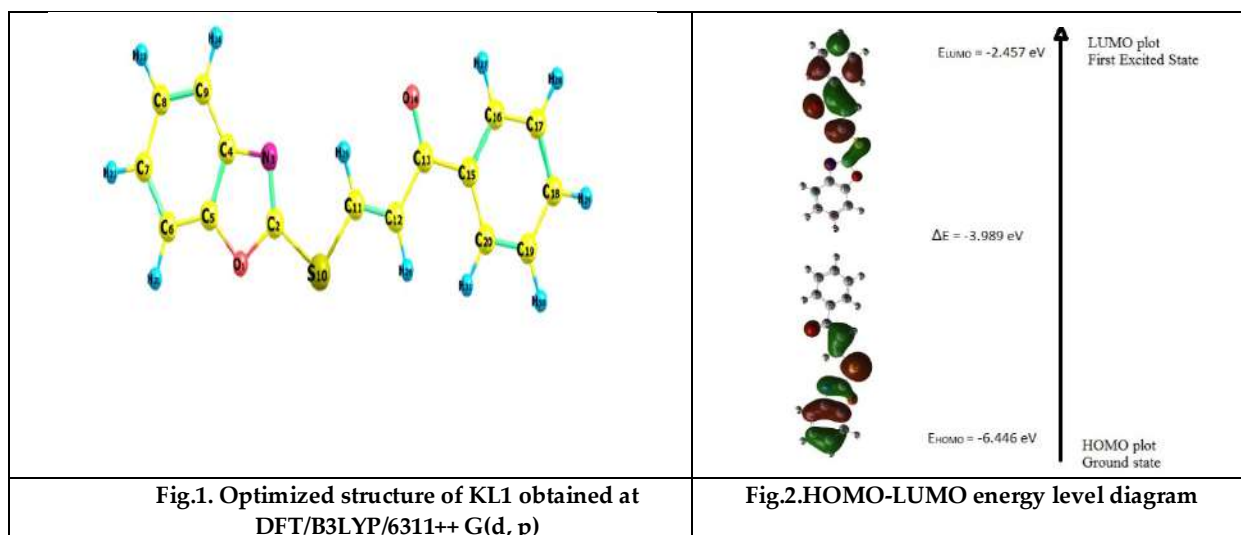
Compound	miLogP	TPSA	nAtoms	nON	nOHNH	n violations	rotb	volume	MW
KL1	2.55	68.4	20	3	0	0	4	241.38	281.38

Table 12: Bioactivity Score

Compound	GPCR Ligand	Ion Channel Modulator	Kinase Inhibitor	Nuclear Receptor Ligand	Protease Inhibitor	Enzyme Inhibitor
KL1	0.43	0.97	0.69	0.86	0.51	0.24

Table 13: Physicochemical and Pharmacokinetics Properties

Molecular formula	C ₁₆ H ₁₁ NO ₂ S	Cytochrome P450 1A2 inhibitor	Yes
Molar refractivity	79.78	Cytochrome P450 2C19 inhibitor	Yes
Lipophilicity (consensus)	3.6	Cytochrome P450 2C9 inhibitor	Yes
Water solubility	Moderately soluble	Cytochrome P450 2D6 inhibitor	No
Gastrointestinal absorption	High	Cytochrome P450 3A4 inhibitor	No
Blood-brainbarrier permeation	Yes	Skin permeation	-5.11
P-glycoprotein substrate	No	Synthetic accessibility scores	2.96





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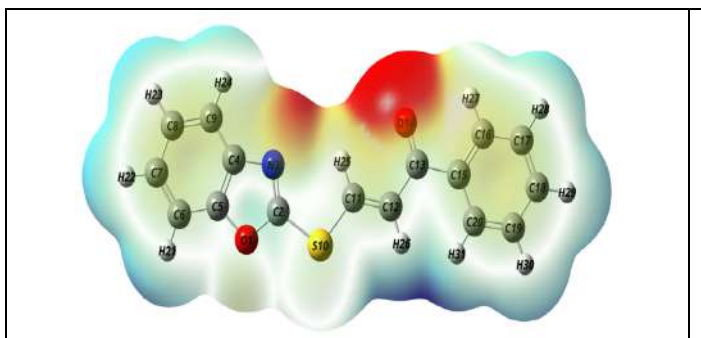


Fig.3. Molecular electrostatic potential surface of the title molecule

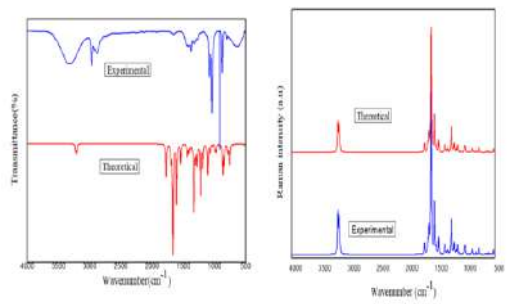


Fig.4. Experimental and theoretical FT- IR and FT-RAMAN spectra of the title compound

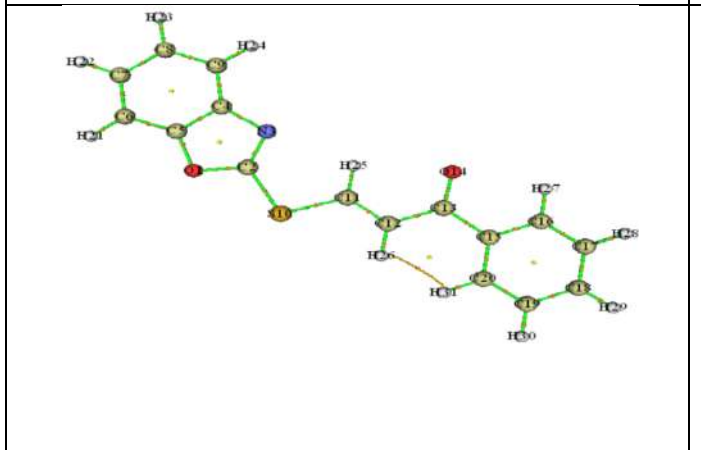


Fig. 5 Topology of electron distribution of the title molecule

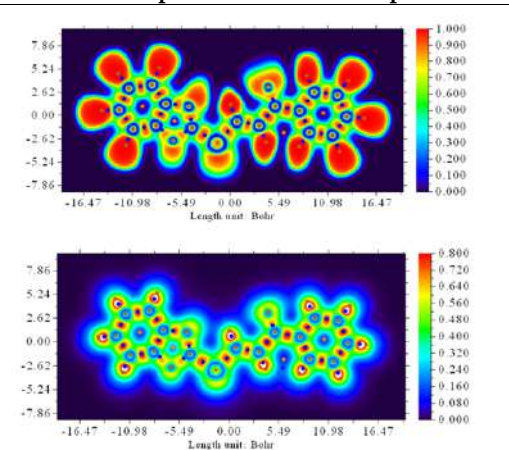


Fig. 6 ELF (top) and LOL (bottom) bond path diagram of the title molecule

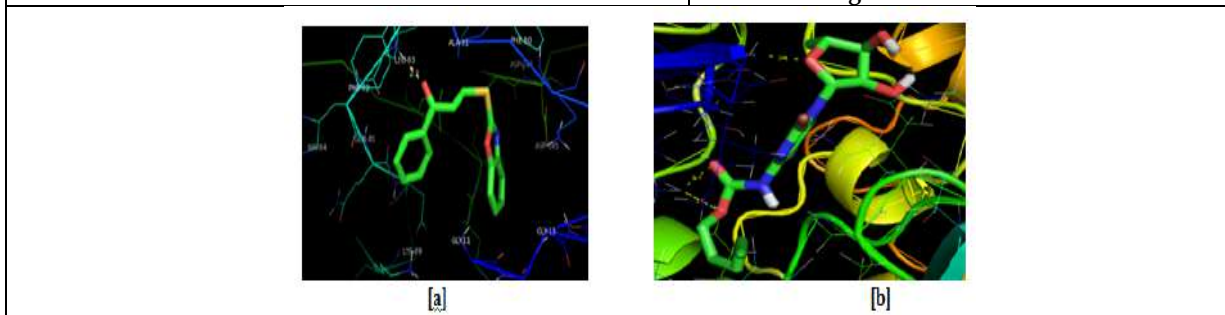


Fig. 7 Pictures depicting interactions between target protein 3QQL and the ligand [a] C1 and [b] co-crystal (Capecitabine)





IoT based Assistive Device for Monitoring quality of Post Harvested Fruits

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ABSTRACT

Next to China, India plays the significant role in production of food and has largest processing unit which is worth of US\$ 70 billion and also involves various smart technologies such as IoT integrated system and blockchains. It has been found that the production of food grains were approximated about 427million tons of food grain which includes rice, wheat, coarse grains and pulses, along with 65 million tons of fruits and 57 million tons of vegetables have also been produced in the year 2019. Though the production of fruits and vegetables in India are high, the processing rate is very low which accounts only for 2.2%. To overcome such losses various different government and non-government organization in India putting forth many solution that involves various smart technologies. *Mangifera indica* (mango), and *Musa .sp* (banana) are the fruits exported from India in large amount. In this research project IoT based Assistive Device for Monitoring quality of Post Harvested Fruits was developed to monitor environmental factors like temperature, humidity, moisture content, ethylene content, carbon dioxide level of the product with the help of sensors. IoT helps in sensing and transmitting the parameters while exporting by means of three ways (water ways, airways, roadways) and during storing in the cold storage rooms indicating the quality of the product. Controlling the environment during transportation and storage will help reduce the spoilage loss and loss that happens due to over ripening. Along with the





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system, GPS has been embedded it can track the travelling location of the product. The producer can watch the status of product and location of the product in their smart phones with the help of GSM.

Keywords: India, Postharvest losses, IoT, Quality Monitoring, Sensors

INTRODUCTION

Fruits and vegetables are one of the most perishable agricultural produce cultivated in India. Since fruits and vegetables are perishable, there occurs postharvest losses in accordance with money that had been invested [1]. Thus this creates large amount economical crisis to the country as well as the farmers who cultivated the fruits and vegetables. The economical crisis mentioned arises when there is a need of proper storing followed by transportation and marketing [1]. The above mentioned issue can be rectified by adopting various smart technologies in areas like handling, harvesting, storing and transportation. Every year, an estimated 1.3 billion ton-roughly one-third -of the food produced for human consumption worldwide is lost or wasted [9]. Next to China, India plays the significant role in production of food and has largest processing unit which is worth of US\$ 70 billion and also involves various smart technologies such as IoT integrated system and blockchains. In 2019, the production was 427 million tones of food grain (rice, wheat, coarse grains and pulses), 65 million tones of fruits and million tones of vegetables. Though the production of fruits and vegetables in India are high, the processing rate is very low which accounts only for 2.2% [2]. When compared to India, developed countries like USA and China concentrate on reducing wastage by increasing the shelf life of product and with value added products from cultivated fruits and vegetables. By doing so the wastage in USA and China reduces 65 % and 23 %. Fruits and vegetables that are grown in India are (30% to 40%) get wasted yearly. The reason for this wastage are because of gaps in cold chain where poor infrastructure along with improper transportation facility. The important factor plays major role is inaccessibility to cold chain storage as there are no proximity to farms.

These results in instability in prices and farmers cannot get remunerative prices. *Mangifera Indica* (MI), is the botanical name of mangoes. These mangoes play significant role Ancient Ayurvedic and also considered to be one of the indigenous herb packed with medicinal properties. The mangoes have nearly 30 species which comes under genus *Mangifera*. It is prominently grown in tropical areas of the world. Indian mangoes are one of the varieties consumed popularly all over the world as it is rich source of nutrients and varies based on its aroma, flavor, color, size and shape [2]. The mangoes are widely cultivated in and around India such as Andhra Pradesh, Uttar Pradesh, Karnataka, Bihar, Gujarat and Tamil Nadu [3]. Among above mentioned countries Uttar Pradesh plays major role in production mango with different varieties and ranks first in mango production which contributed to about 23.47 %. In the year 2019 -2022, India had a turnover of Rs. 400.21 crores/ 56.11 USD and it is leading exporter mangoes in the world [2]. Banana is a fruits comes from genus *Musa* and one of oldest herbaceous plant. It is widely classified into various types based on color, size and shape, nutritional aspects. Though there are different types of bananas, they all comes under two species which are *Musa acuminata* and *Musa balbisiana*. The bananas are considered to be herb which can grow up to 15 meters of height. Banana is a tropical fruit consumed all over the world for its nutrient aspects. In 2020, India is the leading producer of banana since it is a tropical fruit. States like Tamil Nadu, Maharashtra and Gujarat plays important role in banana production that ranges from 30 to 32 million metric tons which exported to countries like United Arab Emirates. This estimated over six billion Indian rupees worth. This brought hike to Indian economy as well as brought interest among farmers to cultivate bananas in large volume. Though it had its advantage, there also occur large amount of wastage in fruits where there is no proper storing and transportation.





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MATERIALS AND METHODS

Components used

Fruits such Mango and Banana were collected from local farm at Coimbatore. DHT11, MQ2 and MQ7 Gas Sensor, Moisture Sensor, Liquid Crystal Display, Arduino Mega 2560, GSM/GPRS modem, IoT Module were used to built a quality monitoring set up.

Design of Quality Monitor

The sensors involved in detection of fruit quality parameters such as temperature, humidity, moisture, and gases like carbon dioxide and air quality sensor connected together to the Arduino board. The values detected are given as an input to this Arduino board. These analytical signals are then converted into digital signal and the result will be displayed in the LCD. Along with this system IoT and GPS system has been included. The data are collected by sensor are send to cloud server from there it sends message to the producer through mobile phones. The GPS system used will help us locate the location of the produce while travelling through any sort of ways (air ways, waterways, roadways). The results shown in LCD are such cMQ for gas, MQ7 is for CO₂ level, soil is for moisture content.

RESULTS AND DISCUSSIONS

The storage studies of banana and mangoes were conducted with design module at ambient condition and refrigeration condition. The figure 1 (a) & 1(b) shows the MQ2 sensor reading of banana at ambient and refrigeration conditions which sense the volatile compounds of the fruit. As the storage period increases, the volatile compounds production is increased. Volatile compounds are produced as indicators of fruit ripening[5], and they can be classified as primary (present in intact tissues) or secondary compounds (result of tissue disruption). Different fruits produce different volatile compounds, although their precursors are phytonutrients and the resulting volatile compounds are usually esters, alcohols, aldehydes, ketones, lactones and terpenoids. From Research it was found that mangoes are composed of 246 volatile compounds out of which only 12 significantly place important role in aroma whereas remaining compounds are 112 esters, 57 alcohols, 39 acids, 10 aldehydes, and 10 ketones, but only 12 compounds contribute significantly to banana aroma[6]. As a result the release of volatile gas has been measured using MQ2 sensor. The rate of ripening is faster at ambient condition when compared to refrigeration condition. The cold storage temperature has effect on ripening of fruit which delays the release of volatile compounds. Cold storage temperature can also affect juice content, fruit firmness, weight loss, reduction of pulp content, decrease of soluble nutrients rate, pH, changes in the pigmentation like internal browning, bleaching, skin/peel darkening, changes in texture, increased rates of electrolyte leakage, surface lesions, failure to ripen and other quality parameters.

Figure 2 (a) and 2 (b) shows the graph depicts on storage studies vs. MQ7 which senses the carbon dioxide level in the storage atmosphere. It is the byproduct of ripening process. And it also helps to detect the spoilage of fruits in case of microorganism infestation. There will be activity of indigenous enzymes in plant tissues. If these enzymes are not destroyed, they continue to function during processing and storage. The peroxidases are the enzyme that is naturally present in fruits can cause off-flavors during storage. In ripening process control over carbon dioxide [CO₂] and Oxygen [O₂] reduces the possibilities of spoilage and maintains its freshness till it reaches the consumer[6]. But there are chances of change in atmospheric concentration in consideration of time since the fruits are able to breathe and produces various gases. Figure 3(a) & 3(b) depicts the changes in gas content of mangoes during both ambient and refrigeration period. As mentioned earlier different volatile compounds could be sensed due to enormous amount of its presence. The different types of volatile compounds such as 7 acids, 55 alcohols, 31 aldehydes, 26 ketones, 14 lactones, 74 esters, 69 terpene hydrocarbons, and 9 other compounds, the changes during maturation are observed[8]. The ripeness is rapid at ambient temperature than cold storage temperature. Figure 4 (a) & 4(b) shows the changes of carbon dioxide content during the storage of both ambient and refrigeration. It shows that, increases in ripening process increases the carbon dioxide content.





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COST

The materials involved in design and development of prototype plays significant role as it should not be neglected.

Overhead Charges

Manufacturing cost (Rs.) = material cost + labor cost

$$=8,750+2000$$

$$= 10,750$$

Overhead charges = 30% of the manufacturing cost

$$= \text{Rs.}3,225$$

Total Cost

Total cost (Rs.) = material cost + labor cost + overhead Charges

$$=8,750+2000+3225$$

$$=13,975$$

Total cost of the design is Rs. 13,975

CONCLUSIONS

The Internet of Things (IoT) is a system of physical devices embedded with sensors and software, interconnected through internet protocol (IP), to perform a task or application with or without human interaction. In agriculture sector, IoT can play an important role for smart farming to collect huge data from sensor and to control the internal processor for efficient farm management. In conclusion to this study, a multisensory module is designed and implemented to sense and display the maturity status of fruits during transportation and storage. The maturity data of the fruits are interfaced with cloud through embedded technique. The result of two fruits banana, and mango have shown more than 90 percent accuracy. The prototype can also be used for other fruit crops and in meat industries.

REFERENCES

1. Yahaya, S. M., & Mardiyah, A. Y. (2019). Review of post-harvest losses of fruits and vegetables. *Biomed. J. Sci. Tech. Res*, 13(4), 10192-10200.
2. https://apeda.gov.in/apedawebsite/SubHead_Products/Mango.htm
3. Rekhapriyadharshini, A. (2015). Study on the Export Performance of Fresh Mangoes from India. *International Journal of Interdisciplinary and Multidisciplinary Studies*, 2(6), 134-140.
4. Kumar, K. S., Bhowmik, D., Duraivel, S., & Umadevi, M. (2012). Traditional and medicinal uses of banana. *Journal of Pharmacognosy and Phytochemistry*, 1(3), 51-63.
5. Berta Gonçalves, Ivo Oliveira, Eunice Bacelar, Maria Cristina Moraes, Alfredo Aires, Fernanda Cosme, Jorge Ventura-Cardoso, Rosário Anjos and Teresa Pinto (2018). Aromas and Flavours of Fruits. Generation of Aromas and Flavours
6. Zhu, X., Li, Q., Li, J., Luo, J., Chen, W., & Li, X. (2018). Comparative study of volatile compounds in the fruit of two banana cultivars at different ripening stages. *Molecules*, 23(10), 2456.
7. <https://www.envirotech-online.com/article/gas-detection/8/edinburgh-sensors/the-use-of-co2-monitoring-in-the-conservation-and-ripening-of-fruits/2568>
8. Singh, Z., Lalel, H. J., & Nair, S. (2002, September). A review of mango fruit aroma volatile compounds-state of the art research. In *VII International Mango Symposium 645* (pp. 519-527).
9. Hegazy, R. (2013). Post-harvest situation and losses in India. *High Court of Karnataka-Bengaluru Bench: WP*, 24739, 2012.
10. Bravo, C. V. G., Ruiz, X. A. V., Nakayo, J. J., Mendiivil, V. T., Castaneda-Olivera, C. A., & Alfaro, E. B. (2022). Biomes of *Mangifera indica* and *Vitis vinifera* for the Production of Biodegradable Sorbets. *Chemical Engineering Transactions*, 92, 523-528.





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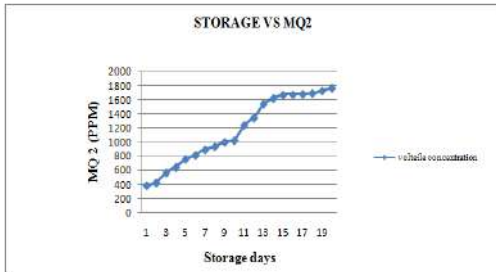


Fig 1(a) Volatile concentration of banana at Ambient temperature

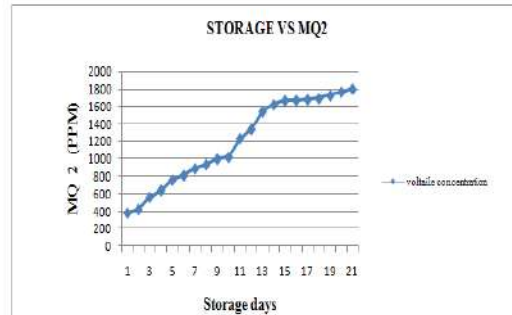


Fig 1 (b) Volatile concentration of banana at Refrigerated temperature

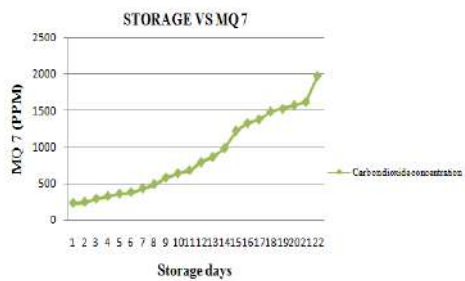


Fig 2(a) Carbon-di-oxide monitoring of banana at Ambient temperature

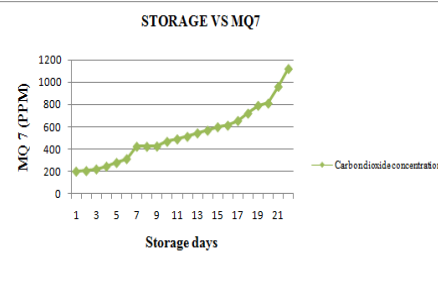


Fig 2 (b) Carbon-di-oxide monitoring of banana at Refrigerated temperature

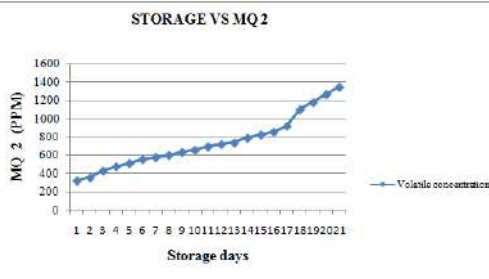


Fig 3(a) Volatile concentration of Mango at Ambient temperature

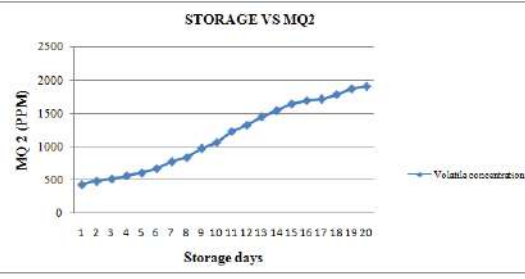


Fig 3 (b) Volatile concentration of Mango at Refrigerated temperature

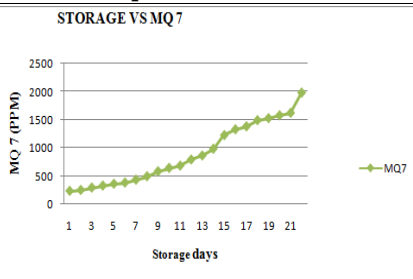


Fig 4(a) Carbon-di-oxide monitoring of Mango at Ambient temperature

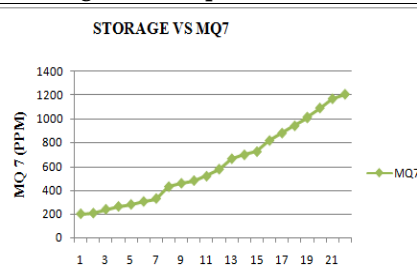


Fig 4(b) Carbon-di-oxide monitoring of Mango at Refrigerated temperature





Navigating Regulatory Norms for Fixed-Dose Combinations in India

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ABSTRACT

In India, the pharmaceutical industry has undergone a substantial transformation, which is shown in the rising acceptance of fixed-dose combinations (FDCs) in medical settings. The FDC which is a combination of more than two APIs in a single dosage form offers several advantages to the patient and in the treatment of several diseases in a wide range of diseases. The aim of this study is to navigate the regulatory roadmap for the registration and approval of the FDC in India. The advantages and disadvantages of the FDC have been discussed in this study along with the importance of FDC in a vast populated country like India. The general regulatory requirements along with specific regulatory requirements and the classification of the FDC have been discussed in this study and the clinical trial requirements for the approval of FDC in India have been discussed. The challenges in registering the FDC in India and requirements for the pharmacovigilance requirements and the pharmacovigilance plan for the FDC have been discussed in the study. In conclusion, the required advancements and the advantages of the FDC have been provided.

Keywords: Fixed dose combination, anti-microbial resistance, central drug standard control organisation, standard treatment guidelines, adverse drug interactions, bridging studies.





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INTRODUCTION

Medicines are an integral part of the health care system. The pharmaceutical business has been investigating ways to make presently accessible medications better, such as by enhancing their usability's safety and effectiveness or by minimizing their negative effects. Then the trend for the production of fixed-dose combinations started.(1)Fixed-dose combination medications are composed of two or more medicinal components combined in a specific dosage form. FDCs are being created more frequently, either to increase compliance or to gain from the additional effects of combining more than one active medication. They are used to treat a variety of ailments, and managing chronic illnesses is where they are most helpful. Every dosage combination should be thoroughly supported by clinical evidence (for instance, where each FDC component has a range of feasible dosages, choosing dosages that have been shown to improve clinical outcomes may be desirable).Although they were frequently employed as second or third-line therapies, FDC medications have been used for a while in several therapeutic categories, such as anti-hypertensives. This delivery technology gained confidence after a revolution in the survival rates of patients with human immunodeficiency virus (HIV) infection that happened with the introduction of fixed drug combination medications for this indication, as well as an influx of innovative applications to other diseases.(2)

ADVANTAGES AND DISADVANTAGES OF FDC

FDC formulations have special benefits such as a complementary mode of action, synergistic effects, greater tolerability, extended drug life-cycle management, and reduced expenses.FDC use is a sensible strategy for maximizing therapeutic effects while minimizing pillburden. Better adherence results from increased convenience and reduced pill burden, which improves therapeutic outcomes and increases cost-effectiveness.(3)

Better medical care: a reduced daily pill requirement during the intense phase—instead of the present 7-8 pills needed for the single medication regimen, just a few FDC pills would be needed.(4)

Patient compliance: FDC has the potential to improve patient compliance by requiring fewer daily doses than monotherapy. The patients' pill burden was reduced, which increased medication compliance.(5)

Synergistic effect: Fixed-dose combinations occasionally come together to form an ideal combination that has a synergistic effect.

Inhibition of microbial resistance: Infectious Pathogens acquire resistance to antibiotics. Microbes may already be resistant to anti-infective agents or they may develop a resistance to them. Different mechanisms produced by various medications can stop this resistance. Compared to monotherapy medications and free dosage combinations, fixed-dose combinations are more efficient at reducing or eradicating antimicrobial resistance.(6,7)

DISADVANTAGES OF FDC

Even though FDC has certain advantages they have different disadvantages in different aspects which should be considered also. The different disadvantages of FDC are as follows.

Drug interactions: According to the chemical characteristics of the ed substances under the environment (acidic/basic/humidity), drug interactions between active ingredients and excipients that are employed in the FDCs may arise. The fixed-dose combinations will also lead to antimicrobial resistance(AMR).Drug interactions are significant problems because they have the potential to alter therapeutic outcomes, lead to potential incompatibilities, and influence stability. The two medications become chemically unstable as a result. A modified tablet in tablet formulation has been created to stop this interaction. The different disadvantages are depicted in Figure 1.(8)



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Importance of FDC in India: In countries like India which has the largest population in the world maintaining public health and also the health of the individuals for certain diseases will be difficult without the advancement in the pharmaceutical sector and the approach to the FDC is a very good choice to maintain the public and also individual health in countries like India. As discussed above there are several advantages to using the FDC.(9) FDC has been a topic of debate in India since the start of FDC because of the lack of regulatory requirements in India. The lack of harmonization and also lack of communication between the state level and central level drug authority led to a series of adverse drug reports in India and it led to an alarming situation and a major pharmacovigilance aspect for the FDC which were marketed in India after the review of kokate committee certain stringent rules were implemented to regulate the FDC in India now the CDSCO has separate guidelines and also include certain rules for manufacturing distribution and sale of the FDC in India. The importance of fixed-dose combinations in India lies in their potential to simplify treatment regimens, reduce costs, improve patient compliance, and address specific healthcare challenges. However, their use should be carefully regulated to ensure patient safety and effectiveness.(10)

Classification of FDC in India

According to CDSCO the FDCs in India are classified into four different categories India this classification is shown in Table 1

General requirements for the approval of FDC

- The document requirements for the approval of FDC vary depending on the category of the FDC. The committee will take into account the following aspects as it examines Patients' safety, drug toxicity, drug abuse, prescription errors, pharmacokinetic and pharmacodynamic incompatibility, the issue of antimicrobial drug resistance, the most recent Standard Treatment Guidelines (STG), risk ratio, patient compliance, and global standing. There are some norms for the registration and authorization of the FDC in India, regardless of the category they fall under, and the paperwork should be submitted based on the above. The following broad standards must be met for FDC approval. An authorization for marketing the FDC will be issued following Schedules Y, 122-D, 122-DA, and 122E.(11)
- Form 44: Form 44 is applied to get permission for the manufacture, and import of a new drug, and form 44 is necessary for FDC as they are also considered as a new drug in the Indian D&C Act 1940
- A Treasury Challan for INR 15,000 or INR 50,000, depending on whether all of the active ingredients have been given more than a year's worth of approval in India. However, if the applicant has already submitted an application and a challan for any single active ingredient approval that is less than a year old, only a challan of 15,000 is needed.(12)
- Complete chemical and pharmaceutical data
- The finished product's physicochemical properties, dosage form, formulation, requirements, and method of examination. the approval of analytical techniques. outline of the process used to make finished goods. data on the recommended dosage form's stability. Information from studies on the breakdown of all solid oral dosage forms.
- A therapeutic explanation for combining them in the suggested ratio, as well as evidence from supporting literature.
- A list of medication interactions between the active components in the FDC that are known or anticipated, together with any implications. This must be created and signed on behalf of the application by a qualified individual.(13)
- Data from clinical trials demonstrating the efficacy and safety of the FDC at the same strength (conducted in other nations, when appropriate), including published data.(14)
- The regulatory status of the FDC in other nations, including those where the medication is marketed, approved, approved as an investigational new drug (IND), and/or withdrawn, if applicable, with justifications; limitations on use, if any, in markets where the medication is marketed; free sale certificate/certificate of drug product from the nation of origin (in situations where the final product of the FDC is imported); and copies of package inserts and marketing materials.(15)



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- Source of bulk pharmaceuticals or raw materials (for those active components that are regarded as new drugs) - If the applicant already holds a manufacturing license for the bulk drug (or drugs), a copy of that license is required. Alternatively, if necessary, a letter of approval from the source that has been authorized to supply the content may be produced.(16)
- The applicant may import the API (in which case the applicant must submit all pertinent paperwork and follow extra steps for API import) or produce the API (in which case the applicant must submit all pertinent paperwork and follow additional requirements for API manufacture) or purchase the API from another source if the applicant lacks authorization to produce any active pharmaceutical ingredient (API) that is considered to be a new drug.
- A copy of the proposed package inserts, which detail the composition, dosage form(s), indications, dose, and route of administration, use in particular populations, warnings, warnings, and precautions, as well as information on the pharmacodynamics and pharmacokinetic properties, interactions, overdose, shelf-life, packaging specifics, and storage and handling instructions.

Specific requirements For FDC to be marketed in India

After the submission of the general required documents, there are some specific requirements to be fulfilled to get the marketing approval in India. The specific requirements will vary based on the category the FDC falls into. The specific requirements are given in Table 2.

Requirements of Clinical and Non-Clinical Data

A critical stage in the creation of novel medications in clinical trials. National drug regulating organizations mandate them to guarantee that medications are suitable for usage in a human population and are both safe and effective. A combination of two or more medications that, although licensed individually, are planned to be in combination for the first time as a FDC requires clinical trials if the FDC is a new chemical entity.(17)

The Indian CDSCO expects clinical trials for the following type of FDC

- The first applicants for each proposed FDC must conduct a comprehensive, four-phase clinical trial in this scenario if the Fixed dose combination is not commercialized in India and one or more of its API components are not licensed in any country.
- If the FDC is promoted abroad. Here, only the Phase III clinical trial (also known as "bridging studies") is required.(18)
- The regulatory body requests in vitro investigations, if the active components of FDCs are licensed and marketed in India and FDC, and are approved in other nations. Only 'sufficient proof' of their safe and effective simultaneous use may be required for approval if FDC is not marketed in any other nation but has a history of concomitant use in India. The FDC approval process in India is depicted in Figure 2(19)

The Role of Pharmacovigilance in ensuring the safety of FDC drugs in India

To guarantee the security of medicine FDCs, pharmacovigilance is essential. These mixtures are frequently employed to enhance comfort, boost therapeutic outcomes, or cater to particular therapeutic demands. Although the safety profile of FDCs can be complex due to the various active components they include, pharmacovigilance aids in monitoring and controlling any potential concerns related to these medications.(20) because of the existence of irrational medications and the side effects that they can produce. The fate and risk posed by FDC are largely determined by pharmacovigilance. Because clinical trials are frequently small, brief, and biased by omitting patients with concomitant conditions, many adverse drug reactions (ADRs) may still be missed, even though medicine is subjected to comprehensive screening before approval. In its policy guidelines for the approval of FDC, the Indian Drug Regulatory Authority sets a pharmacovigilance plan for the FDC makers.(21) The pharmacovigilance plan for the FDC must be developed by the producers following the policy directives. The pharmacovigilance plan should include the following.

- Data on safety from clinical development
- Present risks of an FDC



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- Description of encountered risks
- The population at risk and
- Situations not studied completely
- All potential drug-drug and drug-food interactions are listed in the FDC, either in a separate document with a pharmacovigilance strategy or pharmacovigilance strategies or in the CTD section relating to safety standards.(22)

The key aspects that should be used to implement effective pharmacovigilance plans are.

Adverse Event Monitoring

This includes monitoring and reporting any suspected adverse drug reactions (ADRs) or unexpected safety concerns. By systematically gathering and evaluating safety information, pharmacovigilance helps identify potential risks and supports informed decision-making regarding the continued use, modification, or withdrawal of FDCs.

Risk Assessment and Benefit-Risk Evaluation

Safety data collected through spontaneous reporting, observational studies, and clinical research are analysed to evaluate the likelihood and severity of adverse effects. This information is then weighed against the therapeutic benefits offered by the FDCs.(23)

Problems related to fixed-dose combination

The medications' irrationality is the biggest issue with the FDC. Without proper care, FDCs can have issues such as PD mismatch between the components, where the single drug has an additive/antagonistic effect that reduces efficacy or increases toxicity, PK mismatch, where most efficacy occurs at a different time, chemical incompatibility that reduces shelf life, drug interactions due to shared metabolizing pathways and limitations of smaller dosing titration of. Overcoming the issue of irrationality in India has been made possible by the application of the new rule by CDSCO on the approval procedure of the FDC in India as well as by the banning of the irrational FDC that was previously in the market.(24)

CONCLUSION

The regulatory aspects of FDC in India have changed considerably compared to previous regulations. The use of irrational drugs not only harms the health of the individual but also has a negative impact on the regulatory policy of drugs in India. The recent advancements in regulatory filing and pharmacovigilance have made the FDC more effective and safe medications to use the drug, The combinational treatment of the drugs will show a very good impact on human health and also be very advantageous for different diseases. Still, more advancement in the regulatory part of the approval process will decrease the use and marketing of the irrational FDC in the country. To implement this a stringent regulation is required for the approval of the FDC.

REFERENCES

1. Janczura M, Sip S, Cielecka-Piontek J. The Development of Innovative Dosage Forms of the Fixed-Dose Combination of Active Pharmaceutical Ingredients. *Pharmaceutics* [Internet]. 2022 Apr 11 [cited 2023 Sep 1];14(4). Available from: <http://www.ncbi.nlm.nih.gov/pubmed/35456668>
2. Abu Esba LC, Yousef C, Ismail S, Halim M, Almodaimagh H, Al-Abdulkarim HA, et al. Fixed dose combinations: A formulary decision guide. *Health Policy Technol.* 2021 Jun 1;10(2):100500.
3. Derington CG, Bress AP, Herrick JS, Jacobs JA, Zheutlin AR, Berchie RO, et al. Antihypertensive Medication Regimens Used by US Adults With Hypertension and the Potential for Fixed-Dose Combination Products: The National Health and Nutrition Examination Surveys 2015 to 2020. *J Am Heart Assoc* [Internet]. 2023 Jun 6 [cited 2023 Sep 1];12(11):28573. Available from: <https://www.ahajournals.org/doi/abs/10.1161/JAHA.122.028573>





Gowthami et al.,

4. Sarzani R, Laureti G, Gezzi A, Spannella F, Giuliotti F. Single-pill fixed-dose drug combinations to reduce blood pressure: the right pill for the right patient. *Ther Adv Chronic Dis* [Internet]. 2022 Jun 24 [cited 2023 Sep 1];13. Available from: <https://journals.sagepub.com/doi/10.1177/20406223221102754>
5. Pan F, Chernew ME, Fendrick AM. Impact of Fixed-Dose Combination Drugs on Adherence to Prescription Medications. *J Gen Intern Med* [Internet]. 2008 May [cited 2023 Sep 1];23(5):611. Available from: <https://pubmed.ncbi.nlm.nih.gov/17811113/>
6. Fixed-Dose Combination Drugs [Internet]. [cited 2023 Sep 1]. Available from: https://www.cdc.gov/tb/webcourses/course/chapter6/6_tb_disease_treatment_6_adherence_strategies_fixed_dose_combination_drugs.html
7. Clinical Benefits of Fixed Dose Combinations Translated to Improved Patient Compliance - PubMed [Internet]. [cited 2023 Sep 1]. Available from: <https://pubmed.ncbi.nlm.nih.gov/31801333/>
8. McGettigan P, Roderick P, Mahajan R, Kadam A, Pollock AM. Use of Fixed Dose Combination (FDC) Drugs in India: Central Regulatory Approval and Sales of FDCs Containing Non-Steroidal Anti-Inflammatory Drugs (NSAIDs), Metformin, or Psychotropic Drugs. *PLoS Med*. 2015 May 1;12(5).
9. POLICY GUIDELINES FOR APPROVAL OF FIXED DOSE COMBINATIONS (FDCs) IN INDIA.
10. Tanavade SS, Chougule DD, Naikwade NS. Indian Scenario on Fixed Dose Combinations. *Res J Pharm Technol* [Internet]. 2016 May 31 [cited 2023 Sep 1];9(5):587–90. Available from: <https://rjptonline.org/AbstractView.aspx?PID=2016-9-5-22>
11. Jayasheel BG. Regulatory requirements for marketing fixed dose combinations. *Perspect Clin Res* [Internet]. 2010 [cited 2023 Sep 1];1(4):120. Available from: <https://pubmed.ncbi.nlm.nih.gov/21011111/>
12. FDC New Drugs Marketing [Internet]. [cited 2023 Sep 1]. Available from: https://cdsco.gov.in/opencms/opencms/en/Approval_new/FDC-New-Drugs-Marketing/
13. Roderick P. Regulating new drugs in India needs to be improved. *The Lancet Regional Health - Southeast Asia* [Internet]. 2023 Mar 1 [cited 2023 Sep 1];10. Available from: <https://www.thelancet.com/article/S2772368223000045/fulltext>
14. Dunn K, Rogers R, Simonson RB, Luo D, Sheng S, Kassam PT, et al. Rapid initiation of darunavir/cobicistat/emtricitabine/tenofovir alafenamide in acute and early HIV-1 infection: a DIAMOND subgroup analysis. *HIV Res Clin Pract*. 2021;22(2):55–61.
15. Moses RG, Kalra S, Brook D, Sockler J, Monyak J, Visvanathan J, et al. A randomized controlled trial of the efficacy and safety of saxagliptin as add-on therapy in patients with type 2 diabetes and inadequate glycaemic control on metformin plus a sulphonylurea. *Diabetes Obes Metab*. 2014;16(5):443–50.
16. FDA In Brief: FDA Proposes Four Bulk Drug Substances for Inclusion, 19 Not to Be Included on 503B Bulks List for Use by Outsourcing Facilities | FDA [Internet]. [cited 2023 Sep 1]. Available from: <https://www.fda.gov/news-events/fda-brief/fda-brief-fda-proposes-four-bulk-drug-substances-inclusion-19-not-be-included-503b-bulks-list-use> - Google Search [Internet]. [cited 2024 Feb 27]. Available from: https://www.google.co.in/search?q=FDA+In+Brief%3A+FDA+Proposes+Four+Bulk+Drug+Substances+for+Inclusion%2C+19+Not+to+Be+Included+on+503B+Bulks+List+for+Use+by+Outsourcing+Facilities+%7C+FDA+%5BInternet%5D.+%5Bcited+2023+Sep+1%5D.+Available+from%3A+https%3A%2F%2Fwww.fda.gov%2Fnews-events%2Ffda-brief%2Ffda-brief-fda-proposes-four-bulk-drug-substances-inclusion-19-not-be-included-503b-bulks-list-use&gs_l=hp&ei=5WXdZZfMEK-a4-EP7qWAmAo&iflsig=ANes7DEAAAAAZd1z9Z008609ZB2NEwtWfUJfHNCxumg_&ved=0ahUKEwjX0rag2MqEAXUvzTgGHe4SAKMQ4dUDCBU&uact=5&oq=FDA+In+Brief%3A+FDA+Proposes+Four+Bulk+Drug+Substances+for+Inclusion%2C+19+Not+to+Be+Included+on+503B+Bulks+List+for+Use+by+Outsourcing+Facilities+%7C+FDA+%5BInternet%5D.+%5Bcited+2023+Sep+1%5D.+Available+from%3A+https%3A%2F%2Fwww.fda.gov%2Fnews-events%2Ffda-brief%2Ffda-brief-fda-proposes-four-bulk-drug-substances-inclusion-19-not-be-included-503b-bulks-list-use&gs_l_p=Egdnd3Mtd2l6ItACRkRBIEluIEJyaWVmOiBGREEgUHJvcG9zZXMGmRm91ciBCdWxriERYdWcgU3Vic3RhbmNlcyBmb3IlgSW5jbHVzaW9uLCAxOSBOB3QgdG8gQmUgSW5jbHVkZWQgb24gNTAzQiBCdWxrcyBMAxN0IGZvciBVc2UgYnkgT3V0c291cmNpbmcmRmFjaWxpdlGilyB8IEZEQSBbSW50ZXJ





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17. LM J, RM P, DR M. The Clinical Utility of Compounded Bioidentical Hormone Therapy: A Review of Safety, Effectiveness, and Use. The Clinical Utility of Compounded Bioidentical Hormone Therapy [Internet]. 2020 Sep 22 [cited 2024 Feb 27]; Available from: <https://pubmed.ncbi.nlm.nih.gov/33048485/>

18. GUIDELINES ON FIXED DOSE COMBINATIONS (FDC) GUIDANCE FOR INDUSTRY ON FIXED DOSE COMBINATIONS (FDCs). 2010;

19. Bhaduri S, Kipgen T. 'New Drugs' Approvals in India: An Institutional Perspective. Science, Technology and Society. 2018 Nov 1;23(3):444–62.

20. Many fixed-dose drug combinations in India lack central regulatory approval - Queen Mary University of London [Internet]. [cited 2024 Feb 27]. Available from: <https://www.qmul.ac.uk/media/news/2015/smd/many-fixed-dose-drug-combinations-in-india-lack-central-regulatory-approval.html>

21. India's New Drugs and Clinical Trials Rules: An Industry Perspective | RAPS [Internet]. [cited 2024 Feb 27]. Available from: <https://www.raps.org/News-and-Articles/News-Articles/2019/7/Indias-New-Drugs-and-Clinical-Trials-Rules-An-In>

22. Godman B, McCabe H, Leong TD, Mueller D, Martin AP, Hoxha I, et al. Fixed dose drug combinations - are they pharmaco-economically sound? Findings and implications especially for lower- and middle-income countries. Expert Rev Pharmacoecon Outcomes Res [Internet]. 2020 Jan 2 [cited 2024 Feb 27];20(1):1–26. Available from: <https://pubmed.ncbi.nlm.nih.gov/32237953/>

23. Suke SG, Kosta P, Negi H. Role of Pharmacovigilance in India: An overview. Online J Public Health Inform [Internet]. 2015 Jun 22 [cited 2024 Feb 27];7(2):223. Available from: <http://pmc/articles/PMC4576445/>

24. Chaudhry S. Fixed dose combinations in India- what a way to go! Indian Journal of Pharmacy and Pharmacology [Internet]. 2023 Mar 28 [cited 2024 Feb 27];10(1):45–9. Available from: https://www.researchgate.net/publication/369257674_Fixed_dose_combinations_in_India_what_a_way_to_go

25. Classification of FDC at First Approval | Download Scientific Diagram [Internet]. [cited 2023 Sep 1]. Available from: https://www.researchgate.net/figure/Classification-of-FDC-at-First-Approval_fig6_282871331

Table 1: Classification of FDC according to CDSCO(10,25)

CATEGORISATION OF FDC IN INDIA	
<ul style="list-style-type: none"> Category I 	<ul style="list-style-type: none"> The first class of FDCs consists of products with a novel medication as one or more of the active components. The data that must be presented for these FDCs to be approved for marketing will be similar to the data needed for any new medication, including clinical studies.
<ul style="list-style-type: none"> Category II 	<ul style="list-style-type: none"> FDCs in this category combine APIs that have already been approved or marketed separately in a way that is likely to result in severe PD or PK interactions. If the combination medication has undergone clinical trials in other nations, documentation of these trials should be provided. Additionally, if the combination medication is available for sale in foreign markets, details regarding its regulatory status in those countries should be disclosed.
<ul style="list-style-type: none"> Category III 	<ul style="list-style-type: none"> The third category of FDCs consists of products that are currently on the market but for which it has been suggested to alter the proportion of API components or establish a new medicinal claim.





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	<ul style="list-style-type: none"> To get marketing clearance for this category of FDCs, the required justification, along with published reports (if any), should be presented. Depending on the type of the claim and the data given, permission will be granted.
<ul style="list-style-type: none"> Category IV 	<ul style="list-style-type: none"> The fourth group of Fixed-Dose Combinations (FDCs) comprises medications whose individual active ingredients (or drugs from the same category) have been widely used for a specific purpose for many years. These situations often necessitate their simultaneous use, and there is no intention to make any claims beyond their convenience.

Table 2: specific requirements for approval of FDC

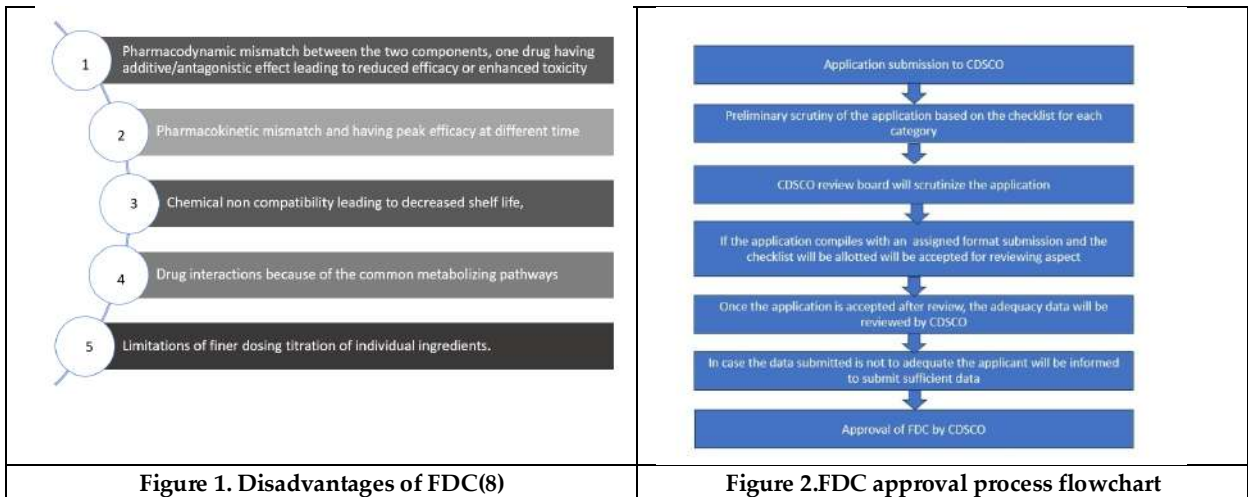
Specific requirements for approval of FDC in India	
CATEGORIES	SPECIFIC REQUIREMENTS
Category I	<ul style="list-style-type: none"> Products falling under the first category of FDCs are those whose proposed combination is unavailable in India and/or whose one or more active components are unique chemical or biological entities. The data that must be presented for consideration for these FDCs to be authorized for commercialization will be equal to the information required for any new drug application, including clinical investigations, as per Schedule Y of the Drugs and Cosmetics Rules of 1945. This category also requires clinical and non-clinical study data.
Category II	<ul style="list-style-type: none"> There is no need for additional clinical trials if the proposed FDC is marketed outside of India or if it is customary to use the individual components simultaneously if an FDC is not marketed in India but the individual active ingredients are approved. The results of bioequivalence research demonstrate that concurrent administration of FDC and active APIs are bioequivalent. Literature on the potential effects of known or anticipated drug interactions between the active medicinal components in the FDC. Data from clinical trials demonstrating the effectiveness and safety of the FDC at the same strength (conducted following good clinical procedures), including published data
Category III	<p>Although FDC is commercialized in India, some modifications are desired. The amount and severity of the product change determine the demand for this sort of FDC.</p> <ul style="list-style-type: none"> If the only adjustment is to the API's ratio and doses of the constituent ingredients fall inside the permitted dosage range for each medicine. The information needs are. Literature on clinical data demonstrating the safety and efficacy of the FDC and concurrent usage of the components, at the strength that is intended to be marketed. <p>List of known and/or anticipated drug interactions between the API components in the FDC, at the suggested levels, and their effects.</p>
Category IV	<ul style="list-style-type: none"> For the later approval of such FDCs for other applicants, the following dossiers (in addition to the common documents) must be submitted: FDCs with the same formulation, indication(s), and strength/ratio as the original applicant's already-approved FDC. The FDC's regulatory status includes information about the different businesses that advertise it.





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	<ul style="list-style-type: none"> • Full chemical and pharmacological information, including stability information for the proposed FDC
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Ayurveda Management of Ashmari (Renal Stone): A Single Case Study

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ABSTRACT

In *Ayurveda*, kidney stones are similar to *Ashmari*. *Ari* denotes an opponent, while *Ashm* has the connotation of a stone. As a result, it acts against the body. Renal stones, a prevalent urological ailment, necessitate a multifaceted treatment approach. This single case study explores the efficacy of *Ayurvedic* medicine as an integrative element in managing renal stones, shedding light on the clinical outcomes and patient-specific nuances. A 24-year-old female patient from Vadodara, Gujarat. Having complained of dysuria, lower back discomfort, haematuria, and vomiting. The female patient has undergone an investigation of ultra sound and was diagnosed with right renal stones. underwent an integrative treatment protocol that combined conventional medical interventions with *Ayurvedic* medicine. The patient's clinical history, diagnostic imaging, and laboratory results were meticulously documented. *Ayurvedic* interventions included *Varunadi Kashaya*, an herbal decoction targeting urinary system health, and dietary modifications based on *Ayurvedic* principles. The patient exhibited symptomatic relief and reduced stone size after six weeks of the integrative approach. accompanied by a significant improvement in associated symptoms, including dysuria, haematuria, etc. *Ayurvedic* interventions were well-tolerated, and the patient reported subjective enhancements in overall well-being. *Ayurvedic* medicine, with its emphasis on restoring *doshik* balance and promoting holistic well-being, contributed to the positive outcomes observed in this case. This single case study suggests that an integrative approach incorporating *Ayurvedic* medicine alongside conventional treatments may offer a promising avenue for renal stone management.



**Nidhi Parmar et al.,****Keywords:** Ayurvedic medicine, renal stones, doshik balance, case study.

INTRODUCTION

A typical issue brought on by changed lifestyles is renal calculi. It is recurring and affects men more often than women. Renal calculi are often diagnosed in people between the ages of 20 and 40, and their frequency declines beyond 50. Renal calculi can be caused by red meat, excessive salt consumption, gout, overuse of certain medications (such as calcium and vitamin D), dehydration, and hot, humid weather. People who drink less water seem to be more susceptible to kidney stones. Renal stones might be calcium oxalate, struvite, uric acid, or cystine. Most commonly, 80% of the population has calcium oxalate stones. Additional examples of the 20% renal stone type were discovered. In *Ayurveda*, the renal stone is comparable to *Ashmari*. One of the diseases included in *Asthamahagada*: e is *Ashmari*.^{[1][2]} In *Ayurveda* mentioned 4 types of *Ashmari*.

1. *Vataja Ashmari* (Stone of Calcium Oxalate)
2. *Pittaja Ashmari* (Stone of Uric Acid)
3. *Kaphaja Ashmari* (Oxalate/Phosphate Stone)
4. *Shukraja Ashmari* (Seminal vesicle stones)

CASE HISTORY

A 24-year-old female patient arrived at the hospital with the following Complaints.

Chief Complaints

The patient had a burning micturition, nausea, vomiting, lower back pain, and constipation for 2 months.

History of Present Illness

Before the 2 months, the patient was in good health. Following that, she experienced dysuria, lower back discomfort, and vomiting. The patient saw a local physician for treatment. However, when there was no improvement, the patient went to the OPD for further care. Once more, blood urea, serum creatinine, urine analysis, and complete count were assessed in the patients.

Investigations

Ultrasonography (KUB), routine blood investigation (complete blood count, blood urea, Serum Creatinine), and Urine analysis were carried out before and after treatment.

Past History

She had no history of Diabetes Mellitus, Hypertension, Asthma, Hypothyroidism, or any Surgery.

Family History- Father –NAD, Mother-NAD

Clinical Examination *Ashtavidha Prakisha:*

- *Nadi-PittaVata*
- *Mala-Samyaka*
- *Mutra- Daha*
- *Jioha- Sam*
- *Shabda- Prakrut*
- *Sparsha- Ushna*
- *Druka- Prakrut*
- *Aakruti- Madhyam* Per Abdomen Examination elicited tenderness on the right lumbar region of the Abdomen. No other Abnormality was Detected during the general and systemic examination.
- *Agni- Vishmagni*





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Vital Parameters- Vital Parameters were normal.

USG report Shows(25/11/2023)

Right distal ureteric calculus(6mm × 3.8mm)& left ureteric calculus(4.8mm × 2.4mm) with resultant hydronephrosis.

MATERIAL AND METHODS

- Presenting Complaints of Patient's Treatment Plan for 1 month:

Instruction given to the patient

Along with *Ayurvedic* medication diet and lifestyle restrictions were also advised for the Patient.

RESULTS AND DISCUSSIONS

The calculi category involves four specific types primarily associated with the *Kapha Dosha*: *Kaphajashmari*, *Pittajashmari*, *Vatajashmari*, and *Shukrajashmari*.^[3]The individual was diagnosed with *Ashmari* and subsequently underwent treatment with medications targeting the key components of the pathology, including *Aharaj mala (Mutra)*, *Kapha* and *Pitta dosha*, and *Jatharagni*. The chosen medications were selected for their *Deepan-pachan*, *Chedan-Bhedan*, and *Lekhan* properties, aiming to assess their efficacy in treating *Ashmari*.^{[3][4]} *Mutrashmari* can be correlated with urolithiasis. It's among the most typical and excruciating disorders of the urinary tract. Under *Ashtamahagada*, *Acharya Sushruta* has explained the situation of *Mutrashmari*. Anywhere in *Mutravaha srotas* can support the growth of *Ashmari*. It is determined that the type of pain depends on the differences in its distinguishing traits. the place where the stone is stuck.^[5] Drugs from *Ayurveda* have the potential to be antipathogenic through a variety of mechanisms, including diuretic effect, physiological pH adjustment, regulation of crystalloid imbalance, antibiotics, analgesics, and an improvement in renal function.^[6] Even after surgery, the production of new stones continues. There are currently no identified drugs or therapies. This process alters a person's lithogenic potential, causing the stone to disintegrate or fracture. *Ayurvedic* medicines, such as *Varuna* and *Punarnava*, might help. All *yogas* have diuretic or lithotriptic components; no single medicine effectively removes stones. Controlling urinary tract infections can help avoid *Ashmari*. All *yogas* employ the four medications mentioned above, regardless of *doshas*. Various medications are used as *dosha* alleviators. Reducing the recurrence rate of uric acid stones is crucial since they can reoccur quickly.^{[4][5]} Antispasmodic, antiseptic, and painkiller medications are used in the treatment of kidney stones, together with hydration. Small kidney stones are easier to pass through the urine when well hydrated. A surgical procedure called lithotripsy is used on patients who have kidney stone recurrence. However, there is a potential that surgery will cause problems.^[7]

CONCLUSIONS

In conclusion, the *Ayurvedic* management of renal stones, as observed in this single case study, appears to show promising results in terms of symptom alleviation and overall well-being of the patient. The holistic approach of *Ayurveda*, which includes dietary modifications, herbal medications, and lifestyle recommendations, seems to contribute to the prevention and dissolution of renal stones. While this case study provides encouraging insights, it is crucial to approach *Ayurvedic* interventions for renal stones with caution and under the guidance of qualified healthcare professionals. Further exploration and validation of *Ayurvedic* practices through rigorous scientific research will contribute to a better understanding of their potential role in managing renal stones.

REFERENCES

1. Rubi R, Singh S, Dwivedi AK. A Case Study on Ayurvedic Management of Ashmari (Renal Calculi). Int. J. AYUSH CaRe. 2023;7(3):262-267.





Nidhi Parmar et al.,

2. Savita Hiremath: A Conceptual Study on Ashmari. ayurpub 2017;II(1):364-368
3. parmar D, Patel J, Padadharia D, Ninama D, Ayurvedic Management of Ashmari –A Single Case Study, Asian Journal of Pharmaceutical Research and Development. 2023; 11(4): 56-60.DOI: <http://dx.doi.org/10.22270/ajprd.v11i4.1308>
4. Dr. Palak Rathod, & Dr. Manjunath Adiga. (2020). Role of Basti in the management of pain in Ashmari (Renal Calculi). *Journal of Ayurveda and Integrated Medical Sciences*, 5(04), 289-291. <https://doi.org/10.21760/jaims.v5i04.984>
5. Samaranayake, G.V.P., Peiris, K.P.P. and Pushpakumara,A.A.J. 2019. An Ayurvedic Approach in the Management of Ashmari (Urolithiasis). *International Journal of Current Innovations in Advanced Research*, 2(3): 13-22
6. Jyoti P. Rajole, Panchal Vinayak J, Chandrakanth Halli. Varunamula Twak KwathainMootrashmari as Ideal Ashmarighna - A Case Study. *JAyurveda Integr Med Sci* 2017;4:329-331.<http://dx.doi.org/10.21760/jaims.v2i4.9378>

Table 1: Presenting Complaints of Patient's Treatment Plan for 1 month

Sr.No	Name of Drug	Dose of Drug	Kala	Frequency and Anupana
1.	<i>Chitrkadi vati</i>	2 Tab.	Before food	Twice a day with Lukewarm water
2.	<i>Varunadi Kasaya</i>	15 ml	Before food	Twice a day with Lukewarm water
3	<i>Pashanbheda Churna</i>	4 gm	After food	Twice a day with Lukewarm water
4.	<i>Shweta Parpati</i>	500 mg	After food	Twice a day with <i>Narikela jala</i>

Table 2:Qualitative analysis based on symptoms

Sr. No.	Symptoms	Before Treatment	After Treatment
1	Abdomen Pain	+++	+
2	Burning Micturition	++	-
3	Vomiting	++++	-
4	Constipation	++	-
5	Haematuria	+	-
6	Lower back pain	+++	+

Table 3: Quantitative analysis based on investigation

Date	25/11/2023	29/12/2023
USG	Right distal ureteric calculus(6mm × 3.8mm) & left ureteric calculus (4.8mm × 2.4mm) with resultant hydronephrosis	Right distal ureteric calculus(2mm × 0.2mm) & left ureteric calculus (2.1mm × 0.5mm) with no hydronephrosis
Red blood cells	Occasional/hpf	Occasional
pus cell	8/hpf	1-2/hpf
Crystal	CA++ Oxalate	Not seen
Sugar	Absent	Absent
Protein	Absent	Absent





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Table : 4

Drug	Rasa	Guna	Virya	Vipak	Proprties
Chitrkadi vatti	Katu,Tikta	Laghu, Ruksha	Ushma	katu	Deepan,Pachan
Varunadi kashay	Katu,Tikta, Kashaya	Laghu, Ruksha	Ushma	katu	Kaphamednashak, Mutrala,Bhedan
Pashanbhed	Kashaya, Tikta	Laghu snigdha	sheeta	katu	Tridoshashamaka, Mutrala,Lekhana
Shwet parpatti	Katu,Kashaya, Lavan,Amla	Tiksna,Guru, Snigdha	Ushma	Madhur	Tridoshashamaka, mutrala Swedjanan





A Management of Vatarakta w.s.r. Gout through Ayurveda - A Single Case Study

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ABSTRACT

According to *Ayurveda*, *Vatarakta* is a disease caused by an imbalance in *VataDosha* that affects *RaktaDhatu*. A sedentary lifestyle combined with mental stress, eating a diet strong in protein, not being vegetarian, and drinking too much alcohol are some of the triggers that lead to an acute exacerbation of *Vatarakta*. Management of *Vatarakta* is a challenge as it is a disease due to its morbidity, chronicity, incurability, and comorbidities. Thus an effort has been made to treat this illness using the *Shamana Aushadis* and *Shodhana* techniques that are referenced in many *Ayurvedic* scriptures. In this case study patient was given *TiktaKsheerBasti* with oral medications i.e. *Amrita Guggulu* 2 Tab twice daily, *KaishorGuggulu* 2 tab twice daily, *Trivratavaleha* 1tsp etc. *Panchkarma* procedures along with internal medications showed good results in the management of overall symptoms in this case of *Vatarakta*. *TiktaksheerBasti* is found to have a very important role in the treatment of by considering it as *Vatarakta*.

Keywords: Joint disorder, *Agnidusthti*, *Basti*, Metabolic disorder, Uric acid.





INTRODUCTION

Vatarakta is considered one of the important metabolic disorders. This is caused by the vitiation of *Vata* and *Rakta*, due to different etiological factors. There are 2 types of *Vatarakta*, *UthanaVatarakta* (superficial type) and *GambhiraVatarakta* (deep type) [1]. *Vatarakta* mainly affects the small joints of the hands and feet. The symptoms of *UthanaVatarakta* are *Kandu* (pruritus), *Daha* (burning), *Ruk* (pain), *Ayama*(extension), *Toda* (aching), *Spurana*(throbbing), *Akunjana* (contraction), *Syava-RaktaTwak* (dusky or coppery colouration of skin) and symptoms of *GambhiraVatarakta* are *Swayathu* (edema), *Stambha* (stiffness), *Arthi*(pain), *Tamravarna* (discoloration), *Daha* (burning sensation), *Paka* (suppuration) [2]. Gout's genesis and symptoms are similar to those of *Vatarakta* and it is the most common inflammatory arthritis in men and in older women [3]. The prevalence of Gout varies across populations but is approximately 1-2 % [4]. The prevalence increases with increasing serum uric acid (SUA) and with age. Because of uric acid crystals, progressive renal disease is an important complication. [5]Based on etiology and symptomatology Gout is similar to that of *Vatarakta* Another name for gout is metabolic arthritis. Gout is a metabolic disorder of uric acid that causes hyperuricemia and deposits of crystals of monosodium urate in soft tissues, joints, and renal tubules [6]. Present study reveals that *Vatarakta* can be managed successfully with *Ayurveda* especially *Panchkarma* therapy i.e. *TiktaKsheer Basti*.

MATERIALS AND METHODS

Case report

A 24- year female patient came to the *Panchkarma* OPD at DSRRAU, Jodhpur India with chief complaints of pain and burning sensation in multiple joints and stiffness in spine since 2 years. It was also associated with mild fever, generalized weakness and epigastric pain during empty stomach, and headache.

History of Present Illness

Two years prior According to patient she was asymptomatic. Then suddenly she felt a sharp pain and Burning sensation in her metacarpal joints. The Pain gradually shifted in both knee joints, metatarsal joints and shoulder joint and finally stiffness in spine. As per the patient she had taken allopathic medicines like steroids, analgesics, but did not get relief so she came for *Ayurveda* treatment. No history of any addiction was found. No personal history or family history of any systemic illness was present.

Clinical Findings

On physical examination patient was febrile with body temperature 101°F with Blood pressure 110/60 mm of Hg, Pulse rate- of 75/minute, RR- of 18/minute. No abnormalities were detected in the respiratory, cardiovascular or central nervous system. That was a Gout case that has been diagnosed. On examination patient was apprehensive and aggravated by unbearable pain. She experienced irregular digestion and *Vishamagni*(Unstable digestion function) which interfered with her sleep. Local increase in temperature was observed on several joints. On local examination raise of temperature was present in multiple joints. Tenderness was present. Burning sensation was present in all joints.

Treatment Protocol

After proper clinical examination, patient was diagnosed with *vatarakta* and was advise to undergo *Tiktaksheer Basti*.

Tikta ksheer Basti given for 16 days shows in (Table no 1)

Shamana *Aushada* also given for 3 months shows in (Table no 2)

OBSERVATION

Changes in Serum uric acid and anti ccp level Shows in (Table no 4)

Changes in Subjective criteria (sign and symptoms) Shows in (Table no 4)





DISCUSSIONS

In the present single case study, a patient with chief complaints such as pain, burning sensation in multiple joints, stiffness in Spine, and also generalized weakness. Who was diagnosed with *Vatarakta*(Gout)was taken for the study. The patient came with the above mentioned symptoms,the patient's condition was going towards osteoporosis hence in the treatment of the patient, we started *TiktaKsheer Basti* in the sequence along with *ChandraprabhaVati* and *KaishoreGuggulu* etc. she got relief in generalized weakness, pain, and Burning sensation in all joints after giving this treatment. *TiktaKsheer Basti* is of *Tikta Rasa* which has a predominance of *Vayu&AkashaMahabhuta*. Hence, it has got resemblance toward body elements like *Asthi*(bone tissue). Further *Tikta* drugs have adoptogenicity Proves *Vataghna,Rasayana(Dhatuwardhaka)&* Improve *Dhatwagni*(metabolism fire). It performs *Pachana Karma*, destroys *Srotorodha* (channel obstruction) leading to pacify *Vata Dosh&* improving metabolism [7]. *Madhu* is Increase retention time of *Basti* by counteract the irritative property of *Saindhava*.*Saindhava* satisfies the need for producing an activity that may facilitate ion exchange across the semipermeable intestinal membrane since it includes ions, including NaCl. This ion exchange might aid in the body's removal of vitiated *Doshas*, primarily *Vayu*. *VataDosh* because of its inherent qualities [8]. *PanchatiktaGhrita* is recommended highly for chronic condition, including osteoporosis, osteopenia, arthritis, etc. this medicines *Snigha* or oily properties.*Shatpushapa Kalka* gives required thickness to *Basti*, *Shatpushapa* is believed to have anti-inflammatory effects, making it beneficial for conditions associated with inflammation. *Guduchi* is considered as the *Agryaoushadhi* in *Vatarakta*. *Vatarakta* being a *RaktavahasrotaVyadi*, *Raktavahasrotogani* property of *Guduchi* may be helpful here. Tinosporine (chemical constituent) is natural diuretic agent which may aid in the excretion of serum uric acid. It is also analgesic and anti – inflammatory.

BastiChikitsa is the prime treatment modality of *Ayurveda*. It is also considered as *ArdhaChikitsa*(half treatment) [9]. *Chopchini* is used in the treatment of Cancer, syphilis, Skin diseases, Constipation, urine retention, joint disorders etc. Around 14th century *Chopchini* was popular in European country after it got *Bhavprakash* successful results in treating Gout of King CharlesI [10]. The *PravalPanchamrut* act as *Pittashamak*, *Dahashamak* & *Kshobhanashak*. *Suranjan* as a single drug and compound formulation is effective against gout by reducing Serum Uric Acid level and its effect is superior to Allopurinol. *GodantiBhasma* is prescribed for the treatment of various skeletal disorders such as osteoporosis, arthritis, and bone fractures. Treatment of Headaches and Migraines The cooling and analgesic properties of *GodantiBhasma* make it an effective remedy for alleviating headaches, migraines, and associated symptoms. *KaishoreGuggulu* is a drug of choice in *Vatarakta* (gout). It corrects purine metabolism and checks on uric acid production. Further, it improves the elimination process of uric acid through urine. Anti-inflammatory properties of *Guggulu* [11,12] Important content of *AmritadiGuggulu* is *Guggulu* which possesses the properties of anti-inflammatory, antioxidant, Uricosuric; antirheumatoid helps in breaking the patho-physiology of Gout [13] As *Trivrit* can initiate bowel movement by liquefying the hard stool so it's an easy or smooth bowel evacuator. It has the property to break down the sticky nature of stool by penetrating it. *Vayu* is considered the key factor for making *Krurakosthaso* definitely *Trivrit* reduces *Vayu* by its *Agneya* action through *Usnavirya*. The bodily nourishment is very much necessary in a weak person or in a strenuous state of defecation so by its *Madhura Rasa* it pacifies the *Vata* and nourishes the person. *Trivrit* enhances *Agni* and become able to cleaning the *Pathway* of *Ama* (undigested chyle) [14].

CONCLUSIONS

In this present case on the based on observation and assessment we can conclude that *TiktaKsheerBasti* play effective role in the *Vatarakta* (Gout).In this case study, along with the symptoms of *Vatarakta*, the symptoms of *Vatarakta* were also found, in the treatment of which *AmritadiGuggulu*, *KaishoreGuggulu* were given along with *TiktaKsheer Basti*, in which the symptoms were also relieved by taking *Vatarakta* medicine.





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REFERENCES

1. YadavajiTrikamaji, editor, commentary: AyurvedaDeepika of Chakrapani on CharakaSamhita of Charaka, Chikithsasthana, chapter 29, verse no. 19, Varanasi; ChowkhambhaKrishnadas Academy; p.628. John A. A., Davidson's principles and practice of medicine, 21st edition, 25th chapter, Pg. 1097.]
2. V Vinitha, Kumar Pnkaj, Shailesh, Nagar Mayur A CASE REPORT ON VATARAKTA, (ISSN: 2320 5091) (October, 2017) 5(10).
3. John A. A., Davidson's principles and practice of medicine, 21st edition, 25th chapter, Churchill Livingstone; 2010. Pg. 1097
4. T Mahesh Babu, A. Vijayalakshmi, V Narasimha, Ayurvedic Management of Vataraktaw.s.r to gout-A case study, International Ayurvedical Medical Journal, (April, 2017) 5(4).
5. John A. A., Davidson's principles and practice of medicine, 21st edition, 25th chapter, Pg. 1097.
6. T Mahesh Babu, A. Vijayalakshmi, V Narasimha, Ayurvedic Management of Vatarakta w.s.r. to gout –A case study, international Ayurvedical Medical journal, (April, 2017) 5(4)
7. Dwivedi Amarprakash, Pathrikar Anaya. Management of katigatvata w. s.r. to Lumbar Spondylolisthesis. Ayushdhara, 2017; 4(4). P. 1224-1229.
8. Umakant Roy Rakesh Mishra S. C. Sarvi, S. Sharda Role of Adityapaka Guggulu and Tiktasheera Basti in the Management of Sandhigata Vata with Special Reference to osteoarthritis [Vol 2, Issue 11, Nov 2021] ISSN(online): 2582-7839
9. Vagbhata. Arunadatta, Hemadri. AstangaHridaya. BastiVidhiAdhyaya. 10th edition. Varanasi: ChaukhambhaOrientalia; 2011. Vol p. 286.
10. Prof. K.C. Chunekar, BhavprakashNighantu, ChoukhambhaBharti Academy, Varanasi, 2013; 47.
11. SinghJ2015, Ayurtimes, 27-03-2017, <https://www.ayurtimes.com/kaishore-guggulu/>
12. Shishodia S, Aggarwal BB. Guggulsterone inhibits NF kappa B and ikkapalalphakinase activation, suppresses expression of anti- apoptotic genes products and enhance apoptosis. J Biol. Chem. 2004; 279(45):47148-47158.
13. Jachak SM, Saklani A. Challenges and opportunities in drug discovery from plants. Curr. Sci. 2007; 92: 1251-1257.
14. Taiyeba Tahira Piyali Kundu P. B. Kar Mahapatra Use of shyama Trivrit (operculinaturpentum, Linn.) in various Disorder: An Ayurvedic Literary Review ISSN: 2319-7064 SJIF(2022): 7.942.

Table 1 :Shows Panchkarma procedure

Panchkarma procedures	Content of Basti	Method of administration	Duration
TiktaKsheerbasti	Saindhav(salt)-6gm Madhu(Honey)-40ml Panchtikta Ghrit-40ml ShatapushapaKalka-10gm Guduchi-40gm Godugdha-240ml Ksheerapaak Jala-480ml	Given with Bastiyantra(Enema Pot) before meal in left lateral position	16 days Basti





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Table 2: Shows Shamana Chikitsa

<i>SamanChikitisa</i>	Dose	<i>Anupana</i>	Duration
<i>ChandraprabhaVati</i>	2 tabs twice daily	Luke warm water	3months
<i>KaishorGuggulu</i>	2 tabs twice daily	Luke warm water	3 months
<i>Amrita Guggulu</i>	2 tabs twice daily	Luke warm water	3 months
<i>TrivrorataAvaleha</i>	1 tsp at bed time	Luke warm water	3 months
Combination of- <i>ChopchiniadiChurna</i> 2gm <i>PravalapanchamritaChurna</i> 250mg+ <i>SuranjanaChurna</i> 250mg+ <i>GodantiBhasma</i> 125mg	After meal	Luke warm water	3 months

Table 3:Shows Changes in Serum Uric acid levels

Objective parameters	BT (10/08/2022)	AT (27/12/2022)
Uric acid	9.80mg/dl	2.65mg/dl
Anti ccp	19.75IU/ML	0.98IU/ML

Table 4: Shows Sign and Symptoms (Subjective criteria)

Signs &Symptoms	BT	AT
<i>Daha</i>	3	0
<i>Sandhishool</i>	3	1
<i>Sandhistabd hata</i>	2	0
<i>Sandhishyavata</i>	2	0
<i>Sandhishoth</i>	1	0
<i>Sandhisparshasahatva</i>	2	0





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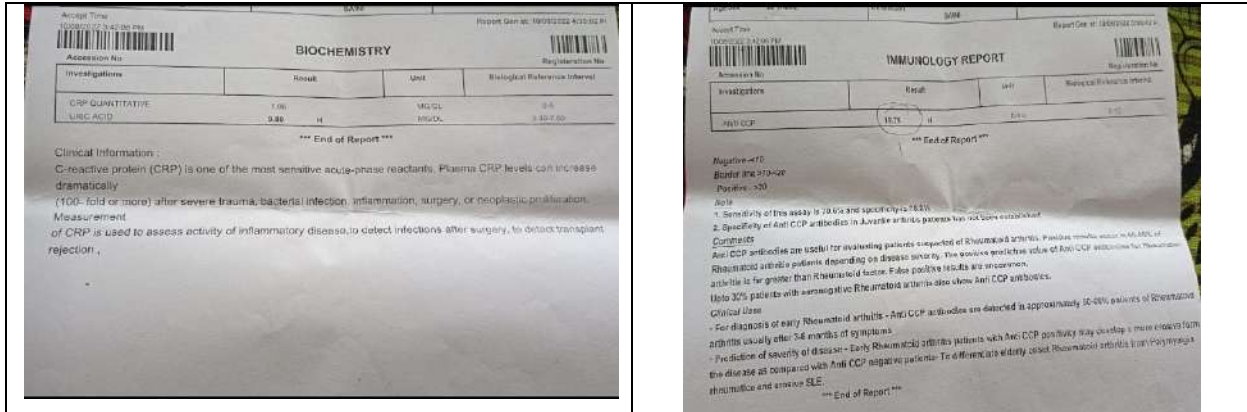


Fig 1: Report before Treatment



Fig 2: Report After Treatment





An Efficient Framework for a Multi-criteria Neutrosophic Decision Making Method based on Kharif Crop Selection

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ABSTRACT

In this paper, one of the multi-criteria models in decision making, a Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), is described using Neutrosophic set. This study helps the farmers to get more profit in Kharif Season crops with the help of seven alternatives (Sugarcane, Cotton, Soyabean, Green gram, Rice, Groundnut, Pigeon pea and four criterions (The Farm area, Crop yield per unit area, The cost prices, The market sales price) for the selection of Kharif Season crops using Neutrosophic linguistic variables. The effectiveness and applicability of this proposed method is illustrated using an example.

Keywords: Multi- Criteria Decision Making (MCDM), Kharif crops, TOPSIS method, Neutrosophic set.

INTRODUCTION

Neutrosophic set concept was first introduced by Smarandache [8]. Multi criteria decision making is one of the most widely used methods in decision making, where options or alternatives are assessed based on a set of criteria [3]. For decision makers it is one of the mathematical tools for the evaluation of criteria performance by Sumin Zhang [9]. TOPSIS is the best solution which has the shortest distance to positive solution [10]. TOPSIS Multi criteria decision making problem was extended by Juanjuan Geng [4] in neutrosophic environment. Eman AboEIHamd [2] defined single valued Neutrosophic sets and some aggregation operators for SVNNS and weighted NS to solve MCDM





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problems. Akanksha Singh [1] proposed score accuracy function for neutrosophic sets. TOPSIS strategy for MACDM in SVNNS was suggested by Nguyen Tho Thog [5]. TOPSIS Multicriteria decision making problem was extended by Odeyinka [6] in fuzzy environment. The organization of this paper is as follows: in section 2 some basic definition of Neutrosophic sets are presented. Section 3 presents the proposed algorithm (NTOPSIS- Arithmetic Average Operator (NTOPSIS - AAO) and NTOPSIS - Geometric Average operator (NTOPSIS-GAO) and Numerical example. Section 4 produces a comparison analysis of the proposed method and Generalized Neutrosophic TOPSIS. Section 5 concludes with conclusion and the future research.

PRELIMINARIES

This section reminds some basic definitions of NSs and SVNNS and its operators. It will be used in the upcoming sections.

Definition: 2.1

A neutrosophic set (NS) is a triple of three independent degrees that are truth (μ_α), Indeterminacy (ρ_α), and falsity γ_α . These degrees are characterized as $\alpha = \{(\mu_\alpha(x), \rho_\alpha(x), \gamma_\alpha(x)) | x \in X\}$, where $\mu_\alpha(x), \rho_\alpha(x), \gamma_\alpha(x)$ is the subset of the non-standard unit interval $(0^-, 1^+)$ such that $0^- \leq \mu_\alpha(x) + \rho_\alpha(x) + \gamma_\alpha(x) \leq 3^+$

Definition: 2.2

A single-valued neutrosophic set (SVNS) α in X is characterized as $\alpha = \{(\mu_\alpha(x), \rho_\alpha(x), \gamma_\alpha(x)) | x \in X\}$, where $\mu_\alpha(x), \rho_\alpha(x), \gamma_\alpha(x)$ is the subset of the non-standard unit interval $[0,1]$ such that $0 \leq \mu_\alpha(x) + \rho_\alpha(x) + \gamma_\alpha(x) \leq 3$ for all $x \in X$.

Definition: 2.3

Let $A_k, k = 1,2,3, \dots, n \in SVNNS(X)$. The single valued neutrosophic weighted arithmetic average operator (SVNAO) (F_w) is described by

$$F_w = (A_1, A_2, \dots, A_n) = \sum_{k=1}^n w_k A_k$$

$$= (1 - \prod_{k=1}^n (1 - \mu_\alpha(X))^{w_k}, \prod_{k=1}^n (\rho_\alpha(X))^{w_k}, \prod_{k=1}^n (\gamma_\alpha(X))^{w_k})$$

Where w_k is the weight of $A_k, k = 1,2,3, \dots, n$ and $w_k \in [0,1]$.

Definition: 2.4

Let $A_k, k = 1,2,3, \dots, n \in SVNNS(X)$. The single valued neutrosophic weighted geometric average operator (SVNGO) is represented by

$$G_w = (A_1, A_2, \dots, A_n) = \sum_{k=1}^n A_k^{w_k}$$

$$= \left(\prod_{k=1}^n (\mu_\alpha(X))^{w_k}, (1 - \prod_{k=1}^n (1 - \rho_\alpha(X))^{w_k}), (1 - \prod_{k=1}^n (1 - \gamma_\alpha(X))^{w_k}) \right)$$

where w_k is the weight of $A_k (k = 1,2,3, \dots, n)$ and $w_k \in [0,1]$.

METHOD

In this section, the Proposed NTOPSIS method algorithms 1 which is NTOPSIS-AAO and algorithm 2 NTOPSIS – GAO are summarized briefly and based on these algorithm Numerical examples are presented.

Proposed Method 1

The procedure for NTOPSIS - AAO using SVNNS. Let $\tilde{A} = \{\tilde{A}_1, \tilde{A}_2, \tilde{A}_3, \dots, \tilde{A}_m\}$ be a set of alternatives and $\tilde{C} = \{\tilde{C}_1, \tilde{C}_2, \tilde{C}_3, \dots, \tilde{C}_n\}$ be a set of criteria and Decision Matrix (DM) be a set of decision – makers as follows $D_m =$





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$\{\mathbb{D}\mathbf{m}_1, \mathbb{D}\mathbf{m}_2, \mathbb{D}\mathbf{m}_3, \dots, \mathbb{D}\mathbf{m}_m\}$. The linguistic variable of criteria and alternatives to be convert to SVNNS. According to the linguistic variable, the SVNNS has to be change.

Step 1: Calculate weight of the k^{th} Decision Matrix

$$\zeta_k = \frac{1 - \left(\frac{1}{5} \left\{ (1 - \mu_{\alpha_k}^{dm}(x))^2 + (1 - \bar{I}_{\alpha_k}^{dm}(x))^2 (1 - \mu_{\alpha_k}^{dm}(x))^2 \right\}\right)^{0.5}}{\sum_{k=1}^l \left[1 - \left(\frac{1}{5} \left\{ (1 - \mu_{\alpha_k}^{dm}(x))^2 + (1 - \bar{I}_{\alpha_k}^{dm}(x))^2 (1 - \mu_{\alpha_k}^{dm}(x))^2 \right\}\right)^{0.5} \right]} \rightarrow \textcircled{1}$$

where $\zeta_k \geq 0$.

Step 2: Construct Neutrosophic Decision Matrix

$$\tilde{Y} = \begin{pmatrix} (\mu_{\alpha_1}(x_1), \bar{I}_{\alpha_1}(x_1), \mu_{\alpha_1}(x_1)) & (\mu_{\alpha_1}(x_2), \bar{I}_{\alpha_1}(x_2), \mu_{\alpha_1}(x_2)) & \dots & (\mu_{\alpha_1}(x_n), \bar{I}_{\alpha_1}(x_n), \mu_{\alpha_1}(x_n)) \\ (\mu_{\alpha_2}(x_1), \bar{I}_{\alpha_2}(x_1), \mu_{\alpha_2}(x_1)) & (\mu_{\alpha_2}(x_2), \bar{I}_{\alpha_2}(x_2), \mu_{\alpha_2}(x_2)) & \dots & (\mu_{\alpha_2}(x_n), \bar{I}_{\alpha_2}(x_n), \mu_{\alpha_2}(x_n)) \\ \dots & \dots & \dots & \dots \\ (\mu_{\alpha_m}(x_1), \bar{I}_{\alpha_m}(x_1), \mu_{\alpha_m}(x_1)) & (\mu_{\alpha_m}(x_2), \bar{I}_{\alpha_m}(x_2), \mu_{\alpha_m}(x_2)) & \dots & (\mu_{\alpha_m}(x_n), \bar{I}_{\alpha_m}(x_n), \mu_{\alpha_m}(x_n)) \end{pmatrix} \rightarrow \textcircled{2}$$

Step 3: Compute the weights of the criteria

$$\omega_j = \left[1 - \prod_{k=1}^l (1 - \hat{T}_{ij}^{(k)})^{\zeta_k}, \prod_{k=1}^l (\hat{I}_{ij}^{(k)})^{\zeta_k}, \prod_{k=1}^l (\hat{F}_{ij}^{(k)})^{\zeta_k} \right] \rightarrow \textcircled{3}$$

Step 4: Weighted Normalized Decision Matrix is

$$R' = \begin{pmatrix} \mu_{\alpha_1.\hat{w}}(x_1), \bar{I}_{\alpha_1.\hat{w}}(x_1), \mu_{\alpha_1.\hat{w}}(x_1) & \mu_{\alpha_1.\hat{w}}(x_2), \bar{I}_{\alpha_1.\hat{w}}(x_2), \mu_{\alpha_1.\hat{w}}(x_2) & \dots & \mu_{\alpha_1.\hat{w}}(x_n), \bar{I}_{\alpha_1.\hat{w}}(x_n), \mu_{\alpha_1.\hat{w}}(x_n) \\ \mu_{\alpha_2.\hat{w}}(x_1), \bar{I}_{\alpha_2.\hat{w}}(x_1), \mu_{\alpha_2.\hat{w}}(x_1) & \mu_{\alpha_2.\hat{w}}(x_2), \bar{I}_{\alpha_2.\hat{w}}(x_2), \mu_{\alpha_2.\hat{w}}(x_2) & \dots & \mu_{\alpha_2.\hat{w}}(x_n), \bar{I}_{\alpha_2.\hat{w}}(x_n), \mu_{\alpha_2.\hat{w}}(x_n) \\ \dots & \dots & \dots & \dots \\ \mu_{\alpha_m.\hat{w}}(x_1), \bar{I}_{\alpha_m.\hat{w}}(x_1), \mu_{\alpha_m.\hat{w}}(x_1) & \mu_{\alpha_m.\hat{w}}(x_2), \bar{I}_{\alpha_m.\hat{w}}(x_2), \mu_{\alpha_m.\hat{w}}(x_2) & \dots & \mu_{\alpha_m.\hat{w}}(x_n), \bar{I}_{\alpha_m.\hat{w}}(x_n), \mu_{\alpha_m.\hat{w}}(x_n) \end{pmatrix} \rightarrow \textcircled{4}$$

To find $\mu_{\alpha_i.\hat{w}}(x_j), \bar{I}_{\alpha_i.\hat{w}}(x_j)$ and $\gamma_{\alpha_i.\hat{w}}(x_j)$

$$R \otimes \hat{w} = \{ \langle x, \mu_{\alpha_i.\hat{w}}(x_j) \rangle, \langle x, \bar{I}_{\alpha_i.\hat{w}}(x_j) \rangle, \langle x, \gamma_{\alpha_i.\hat{w}}(x_j) \rangle | x \in X \}$$

where, $\mu_{\alpha_i.\hat{w}}(x) = \mu_{\alpha_i}(x) \cdot T_j, \bar{I}_{\alpha_i.\hat{w}}(x) = \bar{I}_{\alpha_i}(x) + I_j - \rho_{\alpha_i}(x) \times I_j, \gamma_{\alpha_i.\hat{w}}(x) = \mu_{\alpha_i}(x) + F_j - \mu_{\alpha_i}(x) \times F_j$

Step 5: Calculate Positive Ideal Solution (SVN-PIS) and Negative Ideal Solution (SVN-NIS).

Step 6: Determine separation measures \hat{d}^* and \hat{d}' ,

$$d_i^* = \frac{1}{2n} \sum_{j=1}^n \left[(\mu_{\alpha_i.\hat{w}}(x_j) - \mu_{\alpha^*.\hat{w}}(x_j))^2 + (\rho_{\alpha_i.\hat{w}}(x_j) - \rho_{\alpha^*.\hat{w}}(x_j))^2 + (\gamma_{\alpha_i.\hat{w}}(x_j) - \gamma_{\alpha^*.\hat{w}}(x_j))^2 \right]$$

$$d_i' = \frac{1}{2n} \sum_{j=1}^n \left[(\mu_{\alpha_i.\hat{w}}(x_j) - \mu_{\alpha'.\hat{w}}(x_j))^2 + (\rho_{\alpha_i.\hat{w}}(x_j) - \rho_{\alpha'.\hat{w}}(x_j))^2 + (\gamma_{\alpha_i.\hat{w}}(x_j) - \gamma_{\alpha'.\hat{w}}(x_j))^2 \right]$$

Step 7: Evaluate the RCC

$$RCC_i = \frac{d_i'}{d_i^* + d_i'}, \text{ Where } 0 \leq RCC_i \leq 1$$

Step 8: Determine the rank

Proposed Method 2

Step 1: Calculate weight of the DMs.

Step 2: Determine Decision Matrix

$$\mathbb{D} = \left(\prod_{k=1}^n (T_{ij}^{(k)})^{\zeta_k}, (1 - \prod_{k=1}^n (1 - I_{ij}^{(k)})^{\zeta_k}), (1 - \prod_{k=1}^n (1 - F_{ij}^{(k)})^{\zeta_k}) \right) \rightarrow \textcircled{5}$$

Step 3: Calculate the weights of the criteria

$$\mathfrak{S}_j = \left(\prod_{k=1}^n (\hat{T}_{ij}^{(k)})^{\zeta_k}, (1 - \prod_{k=1}^n (1 - \hat{I}_{ij}^{(k)})^{\zeta_k}), (1 - \prod_{k=1}^n (1 - \hat{F}_{ij}^{(k)})^{\zeta_k}) \right) \rightarrow \textcircled{6}$$

Step 4: Determine Weighted Neutrosophic Decision Matrix.

Step 5: Calculate Positive Ideal Solution (SVN-PIS) and Negative Ideal Solution (SVN-NIS)





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Step 6: Compute Relative Closeness Coefficient (RCC)

Step 7: Calculate rank of the alternatives.

Numerical Example

In this section, the numerical application of Kharif Crops selection is solved by using the modified MCDM technique using neutrosophic set. The proposed approach is applied to select appropriate crops to optimize the profit, optimize the natural resources and promote sustainable agricultural practices. This example contains seven alternatives 1) Sugarcane 2) Cotton 3) Soyabean 4) Green gram 5) Rice 6) Groundnut 7) Pigeon pea and four criterions 1) The farm area 2) Crop yield per unit area 3) The cost prices 4) The market sales price with the help of four different categories of farmers (Marginal, Small, Medium, Large) from which data set of the problem is formed. These selected farmers are categorized by farm area: Marginal: 0.01–< 0.50 acres, Small: 0.50 –< 2.5 acres, Medium: 2.5–< 5.0 acres, Large: –< 5.0 acres. (Then 20 farmers from each category were selected on the basis of probability proportion to their size from both the clusters of the villages, respectively. Thus a total of 80 farmers were surveyed who were raising 1) Sugarcane 2) Cotton 3) Soyabean 4) Green gram 5) Rice 6) Groundnut 7) Pigeon pea) With the given data of farmers, the weights of decision makers was determined and is given in table 1 and using the equation (1), the importance of decision maker's weightage was calculated and is shown in table 2. After that, the single valued neutrosophic decision matrix is computed by using equation (2) and the values are given in the table 3. Calculate the separation measure d_i^* and d_i' with the help of Modified Euclidean Distance and finally the relative closeness coefficient was calculated by using $RCC_i = \frac{d_i}{d_i + d_i^*}$ and the values are shown in table 5.

Comparison Analysis

This section describes the comparison analysis of suggested decision-making strategies using the Rana [7]- described Generalised TOPSIS technique. The TOPSIS procedure described in Rana [7] is contrasted with the decision - making process in this section. The Generalised TOPSIS decision-making procedure is not always appropriate. The TOPSIS system has been altered in two different ways compared to the other MCDM models to manage the critical time, offering flexible and accurate results for selecting the optimum alternative in complex neutrosophic data. The recommended strategy is developed in accordance with observation and acknowledgement of the expertise concept. Its straightforward computation provides us with the finest choice. By using algorithm 2.3.1, the results are as follows: From the above it is clear that the best alternative and the final ranking of all alternative must be made. There is no difference in the final choice of the best solution, but the optimal TOPSIS method is better than the general TOPSIS method because of its correct score among other methods, the calculation is very simple and easy.

CONCLUSION

There are a variety of multiple criteria techniques to aid selection in conditions of multiple-criteria problems. One of them is the TOPSIS method, where the ranking of alternatives is based on the relative similarity to the ideal solution. In this proposed method requires short time and fewer efforts to get the best alternatives. The strength and efficiency of the new approach is explained with numerical example. Comparison analysis is studied with other existing Methods. In future, technique can be implemented in Pythagorean fuzzy Environment.

REFERENCES

1. Akanksha Singh., (2021), "A novel score accuracy function for neutrosophic sets and their real life applications to multi- criteria decision making process", Neutrosophic Sets and Systems, Vol. 4.
2. Eman AboElHamd., Hamed M. Shamma., Mohamed Saleh., and Ihab El-Khodary., (2021), "Neutrosophic Logic Theory and Applications", Neutrosophic Sets and Systems, Vol. 41.
3. Emovon, I., and Ogheniyerovwho, O.S., (2020), "Application of MCDM method in material selection for optimal design", Elsevier, Vol 7.





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4. Juanjuan Geng., Wanhong Ye., and Dongsheng Xu., (2021), "A Method Based on TOPSIS and Distance Measures for Single - Valued Neutrosophic Linguistic Sets and Its Application", International Journal of Applied Mathematics, Vol.51, -11.
5. Nguyen Tho Thog., Luong Thi Hong Lan., Shuo- Yan Chou., Le Hoang Son., Do Duc Dong., and Train Thi Ngan., (2020), "An Extended TOPSIS Method with Unknown Weight Information in Dynamic Neutrosophic Environment", Neutrosophic sets and system, Vol. 8(3), 401.
6. Odeyinka, O.F., Okandeji, A.A., and Sogbesan, A.A., (2022), "A Fuzzy TOPSIS Model for selecting Raw Material Suppliers in a Manufacturing Company", Nigerian Journal of Technology, Vol.41, 797-804.
7. Rana Muhammad Zulqarnain., Xiao Long Xin., Muhammad Saeed., Floreintin Smarandache., and Mohammad Irfan Ahamad., (2021), "An integrated model of Neutrosophic TOPSIS with application in Multi Criteria Decision- Making problem", Neutrosophic Sets and Systems, Vol. 40.
8. Rana Muhammad Zulqarnain., Xiao Long Xin., Muhammad Saeed., Florentin Smarandache., and Nadeem Ahmad., (2020), "Generalized Neutrosophic TOPSIS to solve Multi- Criteria Decision- Making Problems", Neutrosophic Sets and Systems, Vol.38.
9. Sujit Das., Bikash Koli Roy., Mohuya B. Kar., and Samarjit Kar., and Dragan Pamucar., (2020), "Neutrosophic fuzzy set and its application in decision making", Journal of Ambient Intelligence and Humanized, vol.11, 5017-5029.
10. Sumin Zhang., and Jun Ye., (2022), "Multiple Attribute Group Decision- Making Models Using Single Valued Neutrosophic and Linguistic Neutrosophic Hybrid Element Aggregation Algorithms", Journal of Mathematics, vol.1, 1-10.

Table 1: Weights of Decision Matrix

Criteria	Alternative	T	I	F	T	I	F	T	I	F	T	I	F
C_1	A_1	0.5	0.5	0.5	0.5	0.5	0.5	0.9	0.1	0.1	0.7	0.25	0.3
	A_2	0.7	0.25	0.3	0.5	0.5	0.5	0.6	0.35	0.4	0.6	0.35	0.4
	A_3	0.5	0.5	0.5	0.8	0.15	0.2	0.6	0.35	0.4	0.9	0.1	0.1
	A_4	0.7	0.25	0.3	0.6	0.35	0.4	0.5	0.5	0.5	0.6	0.35	0.4
	A_5	0.9	0.1	0.1	0.8	0.15	0.2	0.9	0.1	0.1	0.9	0.1	0.1
	A_6	0.5	0.5	0.5	0.5	0.5	0.5	0.9	0.1	0.1	0.5	0.5	0.5
	A_7	0.8	0.15	0.2	0.7	0.25	0.9	0.1	0.1	0.5	0.9	0.1	0.1
C_2	A_1	0.7	0.25	0.3	0.7	0.25	0.3	0.6	0.35	0.4	0.5	0.5	0.5
	A_2	0.5	0.5	0.5	0.6	0.35	0.4	0.9	0.1	0.1	0.7	0.25	0.3
	A_3	0.5	0.5	0.5	0.8	0.15	0.2	0.7	0.25	0.3	0.7	0.25	0.3
	A_4	0.6	0.35	0.4	0.5	0.5	0.5	0.8	0.15	0.2	0.7	0.25	0.3
	A_5	0.9	0.1	0.1	0.8	0.15	0.2	0.9	0.1	0.1	0.9	0.1	0.1
	A_6	0.8	0.15	0.2	0.7	0.25	0.3	0.9	0.1	0.1	0.5	0.5	0.5
	A_7	0.6	0.35	0.4	0.8	0.15	0.2	0.7	0.25	0.3	0.7	0.25	0.3
C_3	A_1	0.5	0.5	0.5	0.7	0.25	0.3	0.5	0.5	0.5	0.9	0.1	0.1
	A_2	0.7	0.25	0.3	0.8	0.15	0.2	0.5	0.5	0.5	0.6	0.35	0.4
	A_3	0.5	0.5	0.5	0.5	0.5	0.5	0.7	0.25	0.3	0.5	0.5	0.5
	A_4	0.8	0.15	0.2	0.7	0.25	0.3	0.5	0.5	0.5	0.5	0.5	0.5





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	A ₅	0.9	0.1	0.1	0.9	0.1	0.1	0.8	0.15	0.2	0.9	0.1	0.1
	A ₆	0.7	0.25	0.3	0.5	0.5	0.5	0.9	0.1	0.1	0.7	0.25	0.3
	A ₇	0.7	0.25	0.3	0.9	0.1	0.1	0.8	0.15	0.2	0.9	0.1	0.1
C ₄	A ₁	0.5	0.5	0.5	0.8	0.15	0.2	0.5	0.5	0.5	0.7	0.25	0.3
	A ₂	0.7	0.25	0.3	0.8	0.15	0.2	0.5	0.5	0.5	0.6	0.35	0.4
	A ₃	0.5	0.5	0.5	0.5	0.5	0.5	0.7	0.25	0.3	0.8	0.15	0.2
	A ₄	0.5	0.5	0.5	0.7	0.25	0.3	0.7	0.25	0.3	0.5	0.5	0.5
	A ₅	0.9	0.1	0.1	0.8	0.15	0.2	0.9	0.1	0.1	0.9	0.1	0.1
	A ₆	0.7	0.25	0.3	0.5	0.5	0.5	0.9	0.1	0.1	0.8	0.15	0.2
	A ₇	0.5	0.5	0.5	0.9	0.1	0.1	0.8	0.15	0.2	0.5	0.5	0.5

Table 2: Weights of Criteria

	DM ₁			DM ₂			DM ₃			DM ₄		
	T	I	F	T	I	F	T	I	F	T	I	F
Linguistic	0.90	0.10	0.10	0.75	0.25	0.20	0.50	0.50	0.50	0.35	0.75	0.80
Variables	$\mu_{\alpha_1}^{dm}$	$\rho_{\alpha_1}^{dm}$	$\gamma_{\alpha_1}^{dm}$	$\mu_{\alpha_2}^{dm}$	$\rho_{\alpha_2}^{dm}$	$\gamma_{\alpha_2}^{dm}$	$\mu_{\alpha_3}^{dm}$	$\rho_{\alpha_3}^{dm}$	$\gamma_{\alpha_3}^{dm}$	$\mu_{\alpha_4}^{dm}$	$\rho_{\alpha_4}^{dm}$	$\gamma_{\alpha_4}^{dm}$
Weights	$\zeta_1 = 0.3314$			$\zeta_2 = 0.2940$			$\zeta_3 = 0.2201$			$\zeta_4 = 0.1545$		

Table 3: Single Valued Neutrosophic Decision Matrix

	C ₁			C ₂			C ₃			C ₄		
A ₁	0.676	0.315	0.324	0.654	0.3	0.346	0.664	0.318	0.336	0.647	0.315	0.353
A ₂	0.612	0.348	0.388	0.696	0.284	0.304	0.688	0.264	0.312	0.688	0.264	0.312
A ₃	0.716	0.253	0.284	0.685	0.271	0.315	0.553	0.429	0.447	0.612	0.356	0.388
A ₄	0.618	0.339	0.382	0.649	0.306	0.351	0.682	0.274	0.318	0.615	0.35	0.385
A ₅	0.877	0.113	0.123	0.877	0.113	0.123	0.884	0.109	0.116	0.877	0.113	0.123
A ₆	0.649	0.351	0.351	0.777	0.192	0.223	0.726	0.251	0.274	0.743	0.232	0.257
A ₇	0.718	0.15	0.342	0.707	0.241	0.293	0.832	0.148	0.168	0.745	0.239	0.255

Table 4: Weighted Single Valued Neutrosophic Matrix

	C ₁			C ₂			C ₃			C ₄		
A ₁	0.5648	0.45245	0.45769	0.4903	0.4751	0.4929	1.5421	0.4015	0.4129	0.5031	0.4676	0.4821
A ₂	0.5113	0.47073	0.51124	0.5219	0.4633	0.4602	1.5661	0.354	0.3917	0.5353	0.4277	0.4489
A ₃	0.5988	0.39712	0.42371	0.5131	0.4534	0.4693	1.4308	0.4991	0.5113	0.476	0.4996	0.51
A ₄	0.5166	0.4663	0.50889	0.4866	0.48	0.4967	1.5601	0.3625	0.3971	0.4786	0.4947	0.5074
A ₅	0.7333	0.27684	0.28122	0.6576	0.335	0.3198	1.7612	0.2183	0.2194	0.6822	0.31	0.2977
A ₆	0.5426	0.51504	0.50947	0.5824	0.3944	0.3975	1.6039	0.3422	0.3583	0.5776	0.4025	0.4054
A ₇	0.6002	0.23964	0.42812	0.5299	0.4308	0.4519	1.71	0.2523	0.2646	0.5796	0.4083	0.4034





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Table 5: Rank of the Alternatives

	d_i^*	d_i'	RCC	Rank
A_1	0.366	0.041	0.101	6
A_2	0.309	0.071	0.187	4
A_3	0.5	0.024	0.046	7
A_4	0.4	0.051	0.113	5
A_5	0.001	0.591	0.998	1
A_6	0.236	0.135	0.364	3
A_7	0.103	0.32	0.756	2

Table 6: Comparative Ranks

	Generalized TOPSIS		TOPSIS-AOS		TOPSIS-GOS	
	RCC	Rank	RCC	Rank	RCC	Rank
A_1	0.551	3	0.3088	3	0.32601	5
A_2	0.896	1	0.9973	1	0.51233	1
A_3	0.505	4	0.0868	5	0.49043	4
A_4	0.363	5	0.2669	4	0.50984	2
A_5	0.757	2	0.8621	2	0.5	3





A Review on Impurity Profiling

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ABSTRACT

Impurity is not recognised in pharmaceuticals formulation. It is regarded as an unwanted substance. The impurity was introduced during the either the API and the final dose forms can be aged or formulated. The presence of these potentially hazardous chemicals may compromise the safety and efficacy of pharmaceutical dose forms. Impurities in a drug product have a substantial impact on its quality. In this article, we have discussed about the impurity, types of impurity and sources of impurity and limits. We have also listed out the analytical techniques for the identification, qualification and characterization of impurity.

Keywords: Impurity, ICH guidelines, residual solvents, analytical techniques

INTRODUCTION

Various regulatory regulations have made the impurity profile mandatory. In the pharmaceutical industry, impurity is defined as organic compound or undesirable substances that is still the case with APIs are active pharmaceutical ingredients. Substances will be formed during the formulation process as well as the APIs and composition age. These are available. Foreign chemicals have the potential to compromise drug safety and efficacy. Regulatory bodies are becoming more interested in impurity profiling. An impurity Profiling is the description of known and unknown contaminants found in new drugs (1). Impurities in Pharmaceuticals refer to substances that are present in a drug product in addition to the active pharmaceutical ingredient (API) or the intended components. These impurities can be introduced during the manufacturing process or may be inherent in the raw materials used(2). Understanding and controlling impurities is crucial in pharmaceuticals for several reasons:





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Safety

Impurities can pose health risks to patients. Some impurities can be toxic or cause adverse reactions when consumed, even in small quantities. Therefore, strict limits and regulations are in place to verify that the amounts of these contaminants in pharmaceutical products are secure and tolerable.

Quality Control

Impure substances may have an impact on the purity, stability, and efficiency of a medicine. They may alter the drug's chemical properties, leading to variations in its therapeutic effects. Pharmaceutical manufacturers must meticulously monitor and control impurities to ensure consistent product quality.

Regulatory Compliance

Regulatory Compliance: The FDA (Food and Drug Administration) in the United States and the European Medicines Agency (EMA) in Europe have severe norms and requirements addressing contaminants in medications. Manufacturers must adhere to these regulations to gain approval for their products and maintain good manufacturing practices (GMP).

Manufacturing Process Optimization

Understanding impurities can help pharmaceutical companies optimize their manufacturing processes. By identifying the sources of impurities and implementing appropriate controls, manufacturers can improve the efficiency and yield of their production processes.

Stability and Shelf-Life

Impurities can also impact the stability and shelf-life of pharmaceutical products. Some impurities can catalyse chemical reactions that degrade the drug over time. Proper testing and control of impurities help extend the shelf-life of medications.

Types of impurity

Pharmaceutical contaminants are often synthesis formulation-, or degradation-related. Pharmaceutical impurities are categorized into two types:

- 1) Impurities linked with active ingredients APIs are medicinal ingredients.
- 2) Impurities created during the manufacturing process formulations and/or those that have aged relates to the forms that have been developed(3).

According to the ICH guidelines, impurities APIs and their components are classified into the following categories:

- Organic impurities
- Inorganic impurities
- Residual solvents

Organic impurities

Organic pollutants can occur during the manufacturing and/or storage of a drug substance (4). They can be recognisable or unknown, volatile or non-volatile, and contain a variety of substances.

- Initial components,
- by products,
- intermediary molecules, and degrading products are all examples of starting components.
- The ingredients include chemicals, ligands, and catalysts.

Unless each stage of the multi-step synthesis is closely controlled, the most common contaminants detected in all APIs are initial components or intermediates. Regardless of how frequently completed products are rinsed with solvents, residual solvent is always a possibility(5). Impurities can also be created during the manufacture of APIs as the ultimate product degrades. In contrast, decay products from preservation. Organic substances that are commonly found in APIs include formulation to other dosage forms and ageing. In addition, for an optically active single isomer



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medication, an enantiomeric impurity in the AP could be present. Starting materials, by-products, degradation products, reagents, and chiral impurities are the different types of harmful substances.

Starting materials

Because Substances from beginning material or by product can be discovered in any drug ingredient; therefore, adequate care should be made to eliminate them before they harm the finalized products. As an illustration, the last step in the manufacture of baclofen is glutamine, which forms a possible contaminant when it interacts with sodium hydroxide solutions at room temperature. P-chloro phenyl glutaric acid is a kind of glutaric acid(6).

By-products

Byproducts are always a possibility. Since they can be produced by a number of adverse effects such as insufficient responses exaggerated reactions Unwanted contacts include isomerization, dimerization, rearrangement, and unfavorable contact of starting materials or intermediates with biological reagents or catalyst (7).

Inorganic Impurities

Inorganic contaminants may also be introduced during the majority of medication manufacturing procedure. They are frequently identified and identifiable, and they consist of the following: If producers are extremely cautious about contaminants. Obtaining a single end product with 100% yield is relatively rare in current synthetic chemistry; by-product generation is usually a risk (8).

Reagents, ligands, and catalysts

It is quite unlikely that reagents, ligands, or catalysts include chemicals. However, if the producer takes the necessary precautions during the production process, this can present issues in specific procedures.

Excessive metals

Reactors and process fluids are the primary sources of hazardous metals (assuming stainless steel reactors are used). Heavy metal contamination can easily be avoided by employing glass-lined reactors and demineralized water.

Additional components

Centrifugation bags are among the many filtering aids used in large pharmaceutical production plants and various other industries. Activated carbon is also employed in other ways. To avoid these hazardous compounds, fibers and black particles in bulk medicines must be constantly monitored (9).

Residual solvents

Residual solvents are both inorganic and organic liquids used in the manufacturing process. During the preparation procedure, it is difficult to entirely eliminate these solvents. Certain harmful solvents should be avoided when making bulk medications. The other compounds are classified into three groups based on their potential harm to humans (10).

Class I: Benzene (2 ppm) and carbon tetrachloride (4 ppm) should be avoided.

Class II: Methylene chloride (600 ppm limit), methanol (3000 ppm limit), pyridine (200 ppm limit), toluene (890 ppm limit), and acetonitrile (410 ppm limit)

Class III: Acetic acid, acetone, isopropyl alcohol, butanol, ethanol, and ethyl acetate have per day limits of fifty milligrams or lower.

Impurities in the formulation

The components used in the product composition can result in a variety of contaminants in a drug product. During the manufacturing procedure, a variety of conditions may develop. lead degeneration or other adverse response. The





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fluid alone cannot be utilized in the mixture. It provides pollutants of itself, but it also fosters an ideal atmosphere for hydrolysis catalysis (11).

Impurity forms during formulation are

a) method-related

b) environmental.

The following are the key environmental elements that can reduce stability.

- Exposed to high temperatures.
- Light, particularly UV light.
- The humidity.

c) Impurities in the dosage form.

i. Interaction between components.

ii. Typical degradation based on functional group.

- Aromatic synthesis
- Hydrolysis
- Antioxidant decomposition
- Photolytic breakage
- Decarboxylation

Method related

This is an impurity associated with the procedure. Indolin-2-one, for example, is an impurity produced during autoclave Sterilisation was used in the production of diclofenac sodium's parental dosage form. The intramolecular cyclic reaction of diclofenac sodium in the autoclave atmosphere produced an indolinone analogue as a byproduct, as well as sodium hydroxide(12).

Environmental impurities

Environmental impurities are factors that impair the stability of a pharmacological ingredient, such as. Exposure to high temperatures: Many pharmacological substances are heat sensitive by nature.

Light especially UV light

Light, particularly UV light, makes the drug substance unstable.

Humidity

Sterilisation was used in the production of diclofenac sodium's parental dosage form. The intramolecular cyclic reaction of diclofenac sodium in the autoclave environment produced indolence analogue and sodium hydroxide. Humidity has an impact on hygroscopic items, which are sensitive in humid environments. It has an impact on the bulk powder and solid dose forms(13).

Dosage forms related impurities

The dosage form can sometimes affect the drug's stability. Liquid dosage formulations, in general, are extremely susceptible to degradation, contamination, and microbial infestation. Contaminants are influenced by water content, pH of the solution, anions and cations compatibility, mutual interaction with the contents, and main container (14).

Mutual interaction amongst ingredients

Another significant variable that causes pharmaceutical product destabilization is component interaction. Most vitamins deteriorate quickly when stored, and this is especially true in liquid dosage forms(15).

Typical functional group associated degradation

Ester: Esters hydrolysis is the reaction of an ester with water to create ethanoic acid and ethanol.





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Hydrolysis

Hydrolysis is a chemical reaction triggered by water. This is mostly a water-based mechanism that destroys molecular bonds. Sodium acetate, for example, is a salt that is hydrolyzed by adding water and then separated into sodium ions and acetate ions.

Degradation due to oxidation

The breakdown of $C=C$ with the insertion of new carbon and oxygen bonds is known as oxidative degradation. Hydrocortisone, methotrexate, conjugated dienes, nitrite derivatives, and aldehydes are all oxidatively destroyed.

Photolytic cleavage

Photolytic splitting is caused by direct sunlight contact. For example, sunlight produces a photo cleavage process in the manufacturing of ciprofloxacin eye drops, resulting in an ethylenediamine analogue of ciprofloxacin.

Decarboxylation

When we heat P-Amino Salicylic acid, its carboxyl group produces carbon dioxide. Decarboxylation occurred in the case of the Rofloxacillin photoreaction as well(16).

Impurity profiling in residual solvents

Residual solvents are volatile substances that might stay in a product after it has been manufactured. They're common in medications, food, and other items. These solvents are employed during the manufacturing process but must be eliminated to assure the end product's safety and quality (17). Impurities in residual solvents refer to the presence of other substances or chemicals that may contaminate the solvents. These impurities can arise from various sources, including the manufacturing process itself, raw materials used, storage conditions, and handling procedures. Some common impurities found in residual solvents include:

1. **Residual chemicals from the manufacturing process:** During the production of a product, various chemicals are used, such as catalysts, reagents, and solvents. Even though manufacturers aim to remove these chemicals, traces of them may remain as impurities in the final residual solvent.
2. **Contaminants from raw materials:** If the starting materials used in the production process contain impurities, they can transfer to the residual solvents. These impurities might come from natural sources or due to inadequate purification of raw materials.
3. **Degradation products:** Some chemicals used in the production process or the solvents themselves can degrade over time, forming impurities that were not present initially.
4. **Cross-contamination:** Cross-contamination occurs when distinct items are made in the same equipment, resulting in contaminants in residual solvents.
5. **Environmental exposure:** Residual solvents might also pick up impurities from the environment during storage or transportation(18). To maintain the safety of pharmaceutical goods, regulatory bodies. The International Council for Harmonisation of Technical Requirements for Pharmaceuticals for Human Use (ICH) and the United States Pharmacopoeia (USP) have collaborated to develop these guidelines. These standards are two organizations that have produced residual solvent recommendations and limits. Because the presence of certain impurities in residual solvent over permissible levels may have an adverse effect on the efficacy and safety of the completed goods, manufacturers must abide by these guidelines and undergo thorough testing to identify and quantify contaminants (19).

IMPURITIES LIMITS

International Conference on Harmonisation (ICH)

It is used to track human medication intake. The International Conference on Harmonisation (ICH) is unique in that it brings together regulatory bodies and pharmaceutical corporations to debate the intellectual and technical aspects of drug certification (20). The purpose of the ICH is to establish higher criteria to ensure that pharmaceuticals are made and registered in the most efficient and effective manner possible. These initiatives were initiated to promote





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public health, prevent costly duplication of human clinical trials, and reduce the use of animal research, which jeopardises safety and efficacy. The ICH categorises its recommendations into four groups:

Quality guidelines

They perform stability investigations, applicable contamination thresholds, To achieve this quality, An additional adaptable pharmaceutical quality strategy based on good manufacturing practise is required.

Safety guidelines

ICH developed extensive standards for assuring security and reducing potential hazards such as carcinogenicity, genotoxicity, nephrotoxicity are all risks.

Efficacy guidelines

Efficiency recommendations cover research study design, conduct, safety, and reporting. It also includes new sorts of medications created by biotechnological technologies. The primary goal is to create more precise drugs.

Multidisciplinary guidelines

This is not the same as quality, safety, or efficacy. It has both ICH medical words and standard technical text.

Limitations of known impurity and unknown impurity

Reporting Thresholds

Maximum Daily Dose	Threshold
≤ 1 g	0.1%
> 1 g	0.05%

Identification Thresholds

Maximum Daily Dose	Threshold
< 1 mg	1.0% or 5 µg
1 mg - 10 mg	0.5% or 20 µg
>10 mg - 2 g	0.2% or 2 mg
> 2 g	0.10%

Qualification Thresholds

Maximum Daily Dose	Threshold
< 10 mg	1.0% or 50 µg
10 mg - 100 mg	0.5% or 200 µg
>100 mg - 2 g	0.2% or 3 mg
> 2 g	0.15%

Finding contaminants below the 0.1% limit in freshly manufactured drugs is not essential, according to ICH standards, unless suspected impurities are exceptionally powerful or hazardous (21).

The following impurity limits have been established by the ICH:

Impurity concentrations must be less than 0.1% or 1 mg/day when the dose is less than 2 gm/day. Impurity content should be less than 0.05% of total consumption if the dose exceeds 2 gm/day (22).

Limits for impurities in the drug substance

Drug Substance	Limits
Each identified specified impurity	Not more than 0.5 percent
Each unidentified impurity	Not more than 0.3 percent
Total impurities	Not more than 1.0 percent





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Limits for impurities in the degradation products of drugs

Degradation Product	Limits
Each identified degraded product	Not more than 1.0 percent
Each unidentified degraded product	Not more than 0.5 percent
Total degraded products	Not more than 2.0 percent

Analytical Method Development:

To manufacture new drugs at various phases of research, meaningful and trustworthy analytical data is required(23).

- a) Choosing a sample set for the development of an analytical method
- b) Chromatographic condition and phase screening, often employing the linear solvent- strength gradient elution model.
- c) Method optimization to fine-tune parameters relevant to roughness and robustness. The following procedures are commonly used to identify impurities:
 - ✓ Method of isolation
 - ✓ Separation method
 - ✓ Method of Characterization
 - ✓ Method of standard reference
 - ✓ Spectroscopic technique

Chromatographic technique

High Pressure Liquid Chromatography (HPLC)

High-Performance Liquid Chromatography (HPLC) is a popular and powerful analytical technique in chemistry, notably for impurity analysis. HPLC is particularly well-suited for the separation, measurement, and identification of contaminants in a variety of samples. It is helpful in determining the quality of the API starting material and identifying unexpected contaminants (24). Because it is not confined to volatile or stable materials, it is a versatile technique for analysis, and separation is based on the fact that different compounds move at various rates. There are distinct stationary and mobile phases. HPLC is also used to check the stability of pure medicinal substances and medication mixtures. It can be used to quantify degradation products as well as contaminants. It is a valuable method for impurity analysis due to its great sensitivity, precision, and capacity to separate and analyse a large range of chemicals. It is widely utilised in industries such as pharmaceuticals, food and beverage, environmental monitoring, and others where impurity identification and quantification is crucial for quality control, regulatory compliance, and safety. When working with complicated mixes and trace contaminants, HPLC is especially useful (25).

Gas Chromatography (GC)

It is a type of chromatography that is commonly used for substance separation and analysis. It is basically divided into two sorts.' Gas-Liquid and gas chromatography, to be specific. Typically, gas chromatography is used to determine purity or separate the distinct components of a mixture. It is useful in the separation of pure substances from mixtures. It does, however, have considerable disadvantages, such as the requirement for close Pay close attention when working on the instrument. Gas chromatography can be employed only when the compounds can be vaporized without degradation at a tolerable temperature(26). It can be used to calculate the limit of solvent residue and other volatile pollutants in medications. It is also used to characterise raw materials utilised in the synthesis of Pharmaceutical drugs(27).

Thin layer chromatography (TLC)

Thin-layer chromatography (TLC) is a low-cost chromatographic technology frequently employed in impurity analysis. It can be a useful instrument for determining the presence of contaminants in a sample fast (28).It is a quick and easy approach for initial screening and impurity profiling. It can provide a rapid assessment of whether contaminants are present and is especially useful in the early stages of research or quality control in laboratories.





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However, for more detailed and quantitative impurity analysis, supplementary chromatographic procedures may be required. TLC is a method for identifying different components down to trace amounts. This method was used to develop an analytical procedure for determining stability. Its disadvantages include unpredictability, non-quantifiability, and simultaneous decision. TLC sensors rely on interactions between the components and the detecting reagent. TLC is frequently used to determine the quantity of degradation products created during initial degradation and stress tests (29).

Column Chromatography

Column chromatography is a prominent analytical chemistry technique, especially for impurity analysis. It is the separation and purification of separate substances within a mixture based on chemical properties such as polarity or size (30). Column chromatography is a versatile technology that may be adapted for a number of research and filtering purposes. The stationary phase, mobile phase, and column size, as well as the specific analytical processes utilized, will be determined by the type of contaminants and substance being examined. It's a valuable approach in medicine, chemical synthesis, and other industries where impurity analysis is critical for product quality and safety.

Flash Chromatography

Organic substances can be purified by distillation, re-crystallization, or extraction. Flash chromatography is a chromatographic technique used in analytical and preparative chemistry to separate, purify, and analyze chemical molecules, including impurities. It is especially useful when you need to quickly separate and detect pollutants in a sample. Because of its high flow rates, flash chromatography is commonly used for small-scale purification and impurity analysis. When you need to separate components quickly and sample sizes are limited, it is suitable for substance analysis. It is widely used in pharmaceutical and organic chemistry laboratories for substance analysis and purification. The stationary phase and mobile phase, as well as the specific conditions, will be defined by the impurities and compound being studied, allowing for customization based on your substance study's unique needs (31).

Supercritical Fluid Chromatography (SFC)

Supercritical fluid chromatography (SFC) is an analytical separation method used to evaluate contaminants. SFC examines impurities by employing supercritical fluids as the mobile phase, most often CO₂ combined with a co-solvent. SFC is particularly useful for separating compounds that are difficult to separate using conventional chromatographic techniques, and it can be used to discover and quantify contaminants in a wide range of industries, including pharmaceuticals and natural product analysis(32).

High-performance thin layer chromatography:

HP TLC is a modern TLC variation with better separation efficacy but limited detection capabilities. Only HP TLC enables you to display the results as a picture. Sample parallelization, reduced costs, faster findings, and the ability to identify a wide range of components are all advantages (33). The HP TLC approach could assist to lower the danger of harmful organic wastewater exposure while also reducing disposal concerns significantly. With the development of densitometers as detection equipment and stationary phases, HP TLC has made strides in pharmaceutical analysis. It's used extensively in pharmaceuticals, forensic chemistry, clinical chemistry, biochemistry, food and drug analysis, cosmetology, environmental analysis, and other industries (34).

REFERENCES

1. Manikrao, D. O. and K. C. Pradip (2020). "REVIEW ON IMPURITY PROFILING."
2. Xiao, C., et al. (2021). "Elemental impurities in pediatric calcium carbonate preparations-high throughput quantification and risk assessment." *Frontiers in Chemistry* 9: 682798.
3. Roy, J. (2002). "Pharmaceutical impurities a mini-review." *AAPs PharmSciTech* 3: 1-8.



**Gowni Aswini et al.,**

4. Ayre, A., et al. (2011). "Impurity profiling of pharmaceuticals." *Adv Res Pharm Biol* 1(2): 76-90.
5. Connors, K. A., et al. (1986). *Chemical stability of pharmaceuticals: a handbook for pharmacists*, John Wiley & Sons.
6. Jacobs P, Dewe W, Flament A, Gibella M, Ceccato A. A new validation approach applied to the GC determination of impurities in organic solvents. *Journal of pharmaceutical and biomedical analysis*. 2006 Feb 13;40(2):294-304.
7. Ahuja S. Impurities evaluation of pharmaceuticals. (No Title). 1998 Jan.
8. Gorog S, editor. *Identification and determination of impurities in drugs*. Elsevier; 2000 May 19.
9. Ahuja S, Alsante KM, editors. *Handbook of isolation and characterization of impurities in pharmaceuticals*. Academic press; 2003 Jul 18.
10. Ahuja S. Impurities evaluation of pharmaceuticals. (No Title). 1998 Jan.
11. Gimeno P, Besacier F, Bottex M, Dujourdy L, Chaudron-Thozet H. A study of impurities in intermediates and 3, 4-methylenedioxymethamphetamine (MDMA) samples produced via reductive amination routes. *Forensic science international*. 2005 Dec 20;155(2-3):141-57.
12. Thakur L, Ghodasra U, Patel N, Dabhi M. Novel approaches for stability improvement in natural medicines. *Pharmacognosy reviews*. 2011 Jan;5(9):48.
13. Ngilirabanga JB, Samsodien H. Pharmaceutical co-crystal: An alternative strategy for enhanced physicochemical properties and drug synergy. *Nano Select*. 2021 Mar;2(3):512-26.
14. Xu Z, Liu X, Peng J, Qu C, Chen Y, Zhang M, Liang D, Lei M, Tie B, Du H. Tungsten–humic substances complexation. *Carbon Research*. 2022 Jul 18;1(1):11.
15. Mangamma K, Pavani J. NOVEL TECHNIQUES INVOLVED IN IMPURITY PROFILING.
16. Dikpati A, Mohammadi F, Greffard K, Quéant C, Arnaud P, Bastiat G, Rudkowska I, Bertrand N. Residual solvents in nanomedicine and lipid-based drug delivery systems: A case study to better understand processes. *Pharmaceutical Research*. 2020 Aug;37:1-1.
17. Opuni KF, Togoh G, Frimpong-Manso S, Adu-Amoah D, Alkanji O, Boateng KP. Monitoring of residual solvent contamination in herbal medicinal products in Ghana: A pilot study. *Scientific African*. 2021 Sep 1;13:e00825.
18. Tapkir N, Soni F, Sahu AK, Jadav T, Tekade RK, Sengupta P. A comprehensive review on assessment and key control strategies for impurities in drug development with a special emphasis on post-marketing surveillance. *Journal of Pharmaceutical Innovation*. 2021:1-20.
19. Bhavyasri K, Vishnumurthy KM, Rambabu D, Sumakanth M. ICH guidelines–“Q” series (quality guidelines)-A review. *GSC Biological and Pharmaceutical Sciences*. 2019;6(3).
20. Guideline IH. Impurities in new drug products. Q3B (R2), current step. 2006 Jun;4:1-5.
21. Nagpal S, Upadhyay A, R Bhardwaj T, Thakkar A. A review on need and importance of impurity profiling. *Current Pharmaceutical Analysis*. 2011 Feb 1;7(1):62-70.
22. Bari SB, Kadam BR, Jaiswal YS, Shirkhedkar AA. Impurity profile: significance in active pharmaceutical ingredient. *Eurasian J Anal Chem*. 2007 Mar 1;2(1):32-53.
23. Alsante KM, Hatajik TD, Lohr LL, Sharp TR. Isolation and identification of process related impurities and degradation products from pharmaceutical drug candidates, Part I. *American Pharmaceutical Review*. 2001;4:70-8.
24. Patil AR, Ghagare PM, Deshmane BJ, Kondawar MS. Review on Chromatography Principal Types and it's Application. *Research Journal of Pharmaceutical Dosage Forms and Technology*. 2020;12(1):27-32.
25. Yuvaraj M, Ramya G, Reka S. Overview on Impurity Profiling. *Journal of Coastal Life Medicine*. 2023 Jan 11;11:1431-41.
26. Mangamma K, Pavani J. NOVEL TECHNIQUES INVOLVED IN IMPURITY PROFILING. *Analysis*. 2019 Dec 1;15(7):669-80.
27. Billowria K, Ali R, Rangra NK, Kumar R, Chawla PA. Bioactive Flavonoids: A Comprehensive Review on Pharmacokinetic and Analytical Aspects. *Critical Reviews in Analytical Chemistry*. 2022 Jul 23:1-5.
28. Nath D, Sharma B. Impurity profiling-a significant approach in pharmaceuticals. *Current Pharmaceutical Analysis*. 2019 Dec 1;15(7):669-80.





Gowni Aswini et al.,

29. Yuvaraj M, Ramya G, Reka S. Overview on Impurity Profiling. Journal of Coastal Life Medicine. 2023 Jan 11;11:1431-41.
30. Kumar PK, Anusha G, Varun D. CONVERGENCE CHROMATOGRAPHY: AN OVERVIEW.
31. Ullah Q, Mohammad A. Vitamins determination by TLC/HPTLC—a mini-review. JPC–Journal of Planar Chromatography–Modern TLC. 2020 Oct;33:429-37.
32. Kishor R, Purchase D, Saratale GD, Saratale RG, Ferreira LF, Bilal M, Chandra R, Bharagava RN. Ecotoxicological and health concerns of persistent coloring pollutants of textile industry wastewater and treatment approaches for environmental safety. Journal of Environmental Chemical Engineering. 2021 Apr 1;9(2):105012.
33. Ventola CL. Mobile devices and apps for health care professionals: uses and benefits. Pharmacy and Therapeutics. 2014 May;39(5):356.

Table 1: Common impurities which are reported in the APIs:

DRUG	IMPURITY	METHOD
Amphotericin B	Tetraenes	UV spectroscopy
Dextrose	5 hydroxyl methyl furfural	GC
EthambutolHydrochloride	2 amino butanol	TLC
Fluorescene sodium	Dimethyl formamide Neamine	GC
Atropine sulphate	Apo atropine	Spectroscopy
Thiazide	Chlorthalidone	RP-HPLC
Gonadotropin	Elagolix sodium	LC-MS
Epothilone	Xabepilone	HPLC
Morphine	6-monoacetyl morphine	HPLC
Ethambutol HCL	2 amino butanol	TLC
Marcptopurine	Hypoxanthine	Ultra Violet spectroscopy
Dup941	PC, SL, LS	LC-UV diode array
Trinitrotoluene	2, 4-dinitrotoluene	GC-MS
Lumefantrine	Des benzyl keto derivative	HPLC-DAD/UV-ESI/MS
Pholcodine	Pholcodine A, B, C	LC-ESI-MS
Mycophenolate mofetil	Mycophenolic acid	LC/DAD/LC/MS/MS





Silver Nanoparticles in Antidiabetics and Wound Healing

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ABSTRACT

The exceptional qualities of silver nanoparticles (AgNPs) and their prospective uses in a range of therapeutic fields have drawn a lot of interest from the biomedical research community. Silver nanoparticles diverse roles in wound healing and antidiabetic activity are the main topic of this review. AgNPs have showed promise in reducing hyperglycemia and enhancing insulin sensitivity in the context of antidiabetic actions. There are a number of different processes that have been suggested, such as modulating inflammatory responses, oxidative stress reduction, and improved insulin signaling pathways. Researchers have used AgNPs to investigate their potential as an antidiabetic agent in both in vitro and in vivo experiments, with promising results. Furthermore, a great deal of research has been done on AgNPs ability to heal wounds. These make them excellent options for the treatment of diabetic wounds because of their capacity to hasten wound closure, reduce inflammation, and encourage tissue regeneration. AgNPs have antibacterial qualities that help to cure or prevent infections in chronic wounds, a major problem in diabetes patients. However, because of their possible toxicity, AgNPs safety for both internal and exterior application needs to be carefully considered. To maximize their therapeutic advantages and reduce their side effects, AgNPs with precise properties, such size and surface modification, must be synthesized under strict supervision. In summary, antidiabetic and wound healing applications are two areas in which silver nanoparticles have significant potential. It is clear that they have the potential to enhance the lives of people with diabetes and chronic wounds, but further study is required to clarify the underlying processes, optimize their synthesis, and evaluate long-term safety.

Keywords: To maximize their therapeutic advantages and reduce their side effects, AgNPs with precise properties, such size and surface modification, must be synthesized under strict supervision.





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INTRODUCTION

Due to their distinctive physical and chemical characteristics, silver nanoparticles (AgNPs) are being employed more and more in a variety of industries, including medicine, food, health care, consumer goods, and industrial applications. These include strong electrical conductivity, optical, electrical, thermal, and biological characteristics.[1]–[5] Due to their peculiar properties, they have been used for several applications, including as antibacterial agents, in industrial, household, and healthcare-related products, in consumer products, medical device coatings, optical sensors, and cosmetics, in the pharmaceutical industry, the food industry, in diagnostics, orthopedics, drug delivery, as anticancer *Fig 1: TEM image of Silver* agents, and have ultimately enhanced the tumor-killing effects Nanoparticles of anticancer drugs.[6] The great production, solubility, and excellent stability of biologically produced AgNPs are intriguing.[4], [7], [8] Various synthesis techniques have been used to produce AgNPs in order to meet the demand. Conventional physical and chemical procedures generally appear to be exceedingly costly and dangerous.[7], [9] The current study summarizes the key methods for creating silver nanoparticles, as well as the numerous functions of these particles as antidiabetic, antibacterial and antibiofilm, antitumor, and dental, cardiovascular, and wound healing agents. In this review, we will look at the mode of action of silver nanoparticles as well as their toxicity, mechanism, and future challenges.

Synthesis

Silver nanoparticles are created via a variety of processes, including physical, chemical, and biological syntheses. It is important to remember that each strategy has pros and cons of its own. The organism decreases Ag^+ to form Ag^0 during the biological manufacture of silver nanoparticles, either as a capping agent, reducing agent, or stabilizing agent.[10]–[12] Recent years have seen a surge in the use of biological technologies based on natural products derived from plant and microbe sources because of their low cost, high yield, and minimal toxicity on the environment and human body.[13] The creation of nanoparticles has often been accomplished by one of three methods: physical, chemical, or biological.[1]

1. **Physical Methods:** In physical processes, the typical method for creating metal nanoparticles is evaporation-condensation, which may be done in a tube furnace at atmospheric pressure. A carrier gas is created by the vaporization of the source material inside a boat centered at the furnace. The evaporation condensation method has previously been used to create nanoparticles made of a variety of materials, including Ag, Au, Pbs, and fullerene.[14]The two most significant physical techniques are laser ablation and condensation evaporation. The benefits of physical synthesis methods over chemical approaches include the homogeneity of NPs distribution and the lack of solvent contamination in the generated thin films.[8] The physical synthesis of silver nanoparticles at atmospheric pressure has certain drawbacks. For instance, the tube furnace takes up a lot of room, uses a lot of energy to raise the temperature surrounding the source material, and takes a long time to reach thermal stability.[3], [15]
2. **Chemical Synthesis:** Silver nanoparticles are reduced chemically. Controlling the chemical, physical, optical, and electrical characteristics of nanomaterials requires careful attention to their size, shape, and surface morphology. One of the most popular ways to create silver nanoparticles with inorganic and organic reducing agents is by chemical reduction.[16] In either aqueous or nonaqueous solutions, the silver ions (Ag^+) are *Fig 3: chemical synthesis* reduced using a variety of reducing agents, including sodium citrate, ascorbate, sodium borohydride ($NaBH_4$), elemental hydrogen, polyol process, Tollen's reagent, N, N-dimethylformamide (DMF), and poly (ethylene glycol)-block copolymers, hydrazine, and ammonium formate.[17]–[19]
3. **Biological synthesis:** Physical and chemical methods for producing silver nanoparticles are costly, time-consuming, and unsustainable.[20] Therefore, it is crucial to create a system that is both ecologically and economically responsible, free of harmful chemicals and other issues related to chemical and physical manufacturing methods.[21]–[23] Through the control of diverse biological functions, biological approaches



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close these gaps and have several applications in the management of health. Fungi, bacteria, and yeasts *Fig 4: Biological* are used in biological production techniques in *synthesis* addition to plant sources. These sources have made this method highly well-liked for using nanoparticles in medicinal applications. [24]–[26]

Information of Antidiabetic Activity

The creation of silver nanoparticles mediated by *Tephrosiatinctoria* stem extracts was assessed for blood sugar regulation. AgNPs neutralized free radicals, decreased the amounts of the enzymes (α glucosidase and amylase) that hydrolyze complex carbohydrates, and increased the rate at which glucose is consumed.[27] The silver nanoparticles from *Ananascomosus* (L.) have encouraging antidiabetic action. in a way dependent on dosage. The stomach's α -glucosidase enzyme is inhibited by AC-AgNPs.[28], [29] This benefits patient with diabetes who do not use insulin. Additionally, the *Argyrea nervosa* leaf extract-synthesized silver nanoparticles shown strong antidiabetic effects.[29]–[31] The primary enzymes that break down carbs into monosaccharides and lower blood glucose levels are inhibited by them.[32] Hyperglycemia is a hallmark of a group of metabolic illnesses known as diabetes mellitus (DM). Diabetes is brought on by either inadequate insulin production or insulin cellular resistance. Frequently used hypoglycemic substances that increase secretion can reduce blood sugar of insulin or raising the sensitivity of cells.[33]–[35] Recent research has shown that AgNPs produced from plant extracts have antidiabetic potential.[36] AgNPs were synthesized using *Solanumnigrum* leaf extract, and their antihyperglycemic effects were assessed in diabetic rats given alloxan. After administering AgNPs to diabetic rats for 14 and 21 days, they saw a drop in blood glucose levels without experiencing any appreciable acute damage. Additionally, using diabetic rats, they evaluated AgNPs' glucose tolerance. In comparison to glibenclamide, a common antidiabetic medication, the results demonstrated that AgNPs had a good hypoglycemic impact.[37]–[39] AgNPs were shown to be able to efficiently increase insulin secretion and sensitivity by inhibiting protein kinase C isozymes and activating the protein kinase C and PI3K pathway at the insulin receptor substrate level. The effectiveness of AgNPs in lowering insulin resistance and DNA damage was noted.

Information of Wound Healing Activity

Millions of individuals worldwide suffer from problems related to wound healing, which raises mortality and related expenses. There are three primary problems associated with wounds: Microbial infections, maladaptive and persistent inflammation, and an inadequate environment for cell migration, proliferation, and angiogenesis. The "ideal" for assuring the preservation of function is wound healing, which also minimizes scarring and speeds up recovery. It has undergone a great deal of study in order to create the technology. Topical medications like antibiotics and colloids are used in traditional wound care techniques to stop infections and encourage healthy woundhealing processes.[40] A surgical treatment's prognosis is intimately linked to wound healing. The novel therapeutic approach for healing wounds brought about by the recent rapid advancement of nanotechnology still requires further research to fully understand the precise processes by which AgNPs affect wound healing.[41]–[43] The biggest organ in the body, the skin is vital to temperature regulation, homeostasis, sensory perception, and defense against poisons, infections, and injuries.[44] A wound might arise from an accident or purposeful cause, or it can be part of a disease that compromises the integrity of the skin.[45] Due to the fact that silver has antibacterial and anti-inflammatory qualities that aid in the healing of chronic wounds, AgNPs can also be utilized as an intrinsic therapeutic strategy.[46], [47] Using an excision wound model, it was demonstrated that the synthetic AgNPs have wound-healing properties in male albino mice. When compared to either the negative or positive control groups, the animals treated with AgNPs exhibited superior wound-healing activity. While control wounds showed noticeable inflammation, AgNPs-treated wounds showed no signs of microbiological contamination, bleeding, or pus development after therapy.[48]–[50] The biological features of silver nanoparticles, including their antibacterial activity, anti-inflammatory effects, and ability to promote wound healing, are drawing interest for possible therapeutic applications. These qualities might be leveraged to create more effective wound and ulcer dressings. The function of silver nanoparticles in wound healing is reviewed in this article. Furthermore, AgNPs may promote fibroblast differentiation into myofibroblasts, which would cause wound contraction.[51]–[54] AgNPs provide a beneficial effect in wound healing for both postoperative outcomes and clinical wound management.



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MECHANISM OF ACTION

AgNPs Antimicrobial MOA

AgNPs releases Ag⁺ ions upon entering the cell. These are found in the cell walls that contain phosphorus. This results in tiny cell wall depressions and interferes with the development of the cell wall. Ions and other foreign objects can enter the cell through the pits that develop. The osmotic pressure inside cells rises as a result. The cell swells when internal pressure is applied. All of these processes eventually result in cell lysis and cell wall rupture. Gram -ve cells have higher levels of this kind of antibacterial activity than Gram +ve cells. This is because the cell walls of gram-positive bacteria include more cross linked layers of teichoic acid and peptidoglycan. Gram-negative cells contain abundant lipopolysaccharides in their cell walls and little to no peptidoglycan layer. AgNPs therefore interact with Gram -ve cells easily and have a low barrier.[55] In Fig.5. Process of silver's antibacterial properties in action containing nanoparticles.

Anticancer activity of AgNPs

AgNPs releases Ag⁺ ions, which are then taken up by the cell when pits develop in the cell wall. It subsequently travels to the mitochondria, where it combines with thiol groups to bind to the enzyme NADPH dehydrogenase, causing ROS to be released and harming the respiratory cycle. In addition, proteins, phosphorus, and sulfur are interacting with formed ROS in the cell.[56] Inhibiting protein synthesis and cell division, these generated ROS also attach to the phosphorus components of DNA and RNA. When a protein binds to DNA, it aggregates toxically and kills cells. Autophagy is another conceivable mechanism. AgNPs can cause autophagy in human ovarian cancer cells by causing autophagolysosomes to accumulate in the cells. Autophagy primarily functions in two ways. It increases cell longevity at low concentrations. H. viability declines, but high concentrations cause cell death.[56], [57] In Fig.6. Mechanism of silver nanoparticles' anticancer effect in a malignant cell.

Safety and Toxicity

AgNPs' special chemical characteristics can be effectively used in a variety of applications. Research has demonstrated the great efficacy of AgNPs as antimicrobials against eukaryotic microorganisms, viruses, and bacteria.[58]–[60] Silver AgNPs may have negative effects on the human reproductive system since they are known to be present in a number of commercial items, including feminine hygiene products and contraceptive devices.[61]–[63] Due to the widespread usage of these materials in several cosmetics and fabrics, human skin exposure to harmful AgNPs may grow with the use of consumer items. Depending on the amount of silver coating,[64] the quality of the fabric, the pH, and the creation of perspiration, AgNPs may be released from consumer products.[65]–[67] AgNPs were discovered to be secreted from antibacterial fabric goods into the perspiration using fake human skin.[68], [69] In different research, AgNPs caused oxidative stress and cell death in human fibrosarcoma and skin cancer cells using an in vitro method. Furthermore, studies have demonstrated that AgNPs can have a number of negative impacts, including a decrease in the human mesenchymal stem cells' ability to proliferate and chemotaxis, an increase in the cytotoxicity and oxidative stress of human hepatoma HepG2 cells, and more.[70]–[73]

Challenges and Future Direction

Given the discovery of several types of bacteria that are resistant to silver in recent decades, the development of antimicrobial therapies based on nano silver is a contentious topic. The first silver-resistant bacteria were found in a burn wound treated with AgNO₃ in the 1960s, and their isolation from a variety of habitats has continued to this day.[74], [75] Ag-enhanced goods with antibacterial qualities are becoming more and more commercially available.[76]–[79] Ag NPs are being studied in a growing number of toxicological investigations, most of which are conducted in vitro on cell cultures, with lower-order lifeforms, or with embryonic creatures. The lack of suitable instruments for in vivo characterization and evaluation may be the reason for the significant delay in toxicological evaluations of Ag NPs on higher-order species. More thorough research is required to fully understand how agricultural nanoparticles (AgNPs) are transported into the environment as a result of consumer-related activities.[80], [81] Improving models to evaluate AgNPs long-term effects in mammalian systems is a key objective



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for future nanotoxicology research as it will make it possible to plan in vivo experiments with welldefined end goals. The above-discussed newly developed imaging modalities are well-suited for tracking AgNPs in vivo fate and transit, and they may also be able to provide fresh perspectives on toxicological processes.[82]– [84]

We conclude by expressing our hope that future debates on the health benefits and risks associated with Ag NPs will be informed by solid scientific data that comes from well-planned research that make use of the right instruments. These kinds of research are essential to guarantee that the final regulation of Ag-enhanced goods will be based on evidence rather than fear or ignorance.[85]–

[87]

CONCLUSIONS

AgNPs have been thoroughly studied in this work, including their production, toxicity, characteristics, and potential future problems. AgNPs may be synthesized using three general methods: chemical, biological, and physical. The physical technique requires a lot of area, uses a lot of energy, and takes a long time to reach thermal stability, among other disadvantages. Although the main risk with the chemical technique is the toxicity of its byproducts, it offers a simple way to create AgNPs. The green synthesis of AgNPs is gaining popularity due to its affordability and environmental friendliness. AgNPs have favorable physical, chemical, biological, optical, thermal, electrical, and catalytic characteristics, as demonstrated by the current review. However, it's important to remember that AgNPs are poisonous, thus this needs to be taken into account when using them in consumer products. The three main obstacles in green synthesis are time consumption, cost, and simplicity. It might be worthwhile to investigate how this method may be used to create forms other than spherical ones. AgNPs released into the environment should be thoroughly studied using better models than the ones now in use, starting with their origins, methods, and transportation, and ending with their impacts. A continuous-flow tubular microreactor prototype presents a viable option for increasing the production of AgNPs. According to a Malaysian research case, a suitable set of rules to address the various challenges should be in place as soon as feasible due to the rapid growth of the nanotechnology sector, particularly those pertaining to the AgNPs field.

REFERENCES

1. X. F. Zhang, Z. G. Liu, W. Shen, and S. Gurunathan, 'Silver Nanoparticles: Synthesis, Characterization, Properties, Applications, and Therapeutic Approaches', *Int J MolSci*, vol. 17, no. 9, Sep. 2016, doi: 10.3390/IJMS17091534.
2. 'Won HyukSuh a, Kenneth S. Suslick b, Galen D. Stucky a, Yoo-Hun Suh c. "Nanotechnology, nanotoxicology, and neuroscience".Progress in Neurobiology. 2009; (87):133-170. - Google Search'. Accessed: Oct. 31, 2023
3. F. Kruijs, H. Fissan, B. R.-M. S. and E. B, and undefined 2000, 'Sintering and evaporation characteristics of gas-phase synthesis of size-selected PbS nanoparticles', *Elsevier*, Accessed: Oct. 31, 2023. [Online]. Available: <https://www.sciencedirect.com/science/article/pii/S0921510799002986>
4. E. Abbasi *et al.*, 'Silver nanoparticles: synthesis methods, bio-applications and properties', *Taylor & Francis*, vol. 42, no. 2, pp. 173–180, Mar. 2014, doi: 10.3109/1040841X.2014.912200.
5. P. Mukherjee *et al.*, 'Fungus-Mediated Synthesis of Silver Nanoparticles and Their Immobilization in the Mycelial Matrix: A Novel Biological Approach to Nanoparticle Synthesis', *Nano Lett*, vol. 1, no. 10, pp. 515–519, 2001, doi: 10.1021/NL0155274.
6. S. Chernousova and M. Epple, 'Silver as antibacterial agent: ion, nanoparticle, and metal', *AngewChemInt Ed Engl*, vol. 52, no. 6, pp. 1636–1653, Feb. 2013, doi: 10.1002/ANIE.201205923.
7. S. Gurunathan, J. H. Park, J. W. Han, and J. H. Kim, 'Comparative assessment of the apoptotic potential of silver nanoparticles synthesized by *Bacillus tequilensis* and *Calocybe indica*





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- in MDA-MB-231 human breast cancer cells: targeting p53 for anticancer therapy', *Int J Nanomedicine*, vol. 10, no. 1, pp. 4203–4223, Jun. 2015, doi: 10.2147/IJN.S83953.
8. S. Irvani, ... H. K.-R. in, and undefined 2014, 'Synthesis of silver nanoparticles: chemical, physical and biological methods', *ncbi.nlm.nih.gov*, Accessed: Oct. 31, 2023. [Online]. Available: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4326978/>
 9. S. Gurunathan et al., 'Biosynthesis, purification and characterization of silver nanoparticles using *Escherichia coli*', *Colloids Surf B Biointerfaces*, vol. 74, no. 1, pp. 328– 335, Nov. 2009, doi: 10.1016/J.COLSURFB.2009.07.048.
 10. 'Zewde B, Ambaye A, Stubbs Iii J, Raghavan D. A review... - Google Scholar'. Accessed: Oct. 15, 2023
 11. S. D. Solomon, M. Bahadory, A. V. Jeyarajasingam, S. A. Rutkowsky, C. Boritz, and L. Mulfinger, 'Synthesis and study of silver nanoparticles', *J ChemEduc*, vol. 84, no. 2, pp. 322–325, 2007, doi: 10.1021/ED084P322.
 12. K. A. El-Nour, A. Eftaiha, ... A. A.-W.-A. journal of, and undefined 2010, 'Synthesis and applications of silver nanoparticles', *Elsevier*, Accessed: Oct. 31, 2023. [Online]. Available: <https://www.sciencedirect.com/science/article/pii/S1878535210000377>
 13. R. Shanmuganathan et al., 'Synthesis of silver nanoparticles and their biomedical applications-a comprehensive review', *ingentaconnect.comRShanmuganathan, I Karuppusamy, M Saravanan, H Muthukumar, K PonnuchamyCurrent pharmaceutical design, 2019•ingentaconnect.com*, vol. 25, no. 24, pp. 2650–2660, Jul. 2019, doi: 10.2174/1381612825666190708185506.
 14. R. Güzel, G. Erdal, R. Güzel, and G. Erdal, 'Synthesis of Silver Nanoparticles', *Silver Nanoparticles - Fabrication, Characterization and Applications*, Jul. 2018, doi: 10.5772/INTECHOPEN.75363.
 15. 'Pal S L, Jana U, Manna P K, Mohanta G P, Manavalan R. "Nanoparticle: An overview of preparation and characterization". *Journal of Applied Pharmaceutical Science*. 2011; 1(06):228-234 - Google Search'. Accessed: Oct. 31, 2023
 16. Gumel AM, Surayya MM, Yaro MN, Waziri IZ, and Amina AA, 'Biogenic synthesis of silver nanoparticles and its synergistic antimicrobial potency: an overview', 2019, doi: 10.15406/jabb.2019.06.00170.
 17. A. Almatroudi, 'Silver nanoparticles: synthesis, characterisation and biomedical applications', *Open Life Sci*, vol. 15, no. 1, p. 819, Jan. 2020, doi: 10.1515/BIOL-20200094.
 18. S. Ahmed, M. Ahmad, B. L. Swami, and S. Ikram, 'A review on plants extract mediated synthesis of silver nanoparticles for antimicrobial applications: A green expertise', *J Adv Res*, vol. 7, no. 1, pp. 17–28, Jan. 2016, doi: 10.1016/j.jare.2015.02.007.
 19. 'Rai M, Yadav A, Gade A. "Silver nanoparticles as a new generation of antimicrobials". *Biotechnology Advances*. 2009; 27:76-83.- Google Search'. Accessed: Oct. 31, 2023.
 20. M. Rafique, I. Sadaf, M. S. Rafique, and M. B. Tahir, 'A review on green synthesis of silver nanoparticles and their applications', *Artif Cells NanomedBiotechnol*, vol. 45, no. 7, pp. 1272–1291, Oct. 2017, doi: 10.1080/21691401.2016.1241792.
 21. 'Amarendra DD, K.G., "Biosynthesis of silver and gold nanoparticles using *Chenopodium album* leaf extract". *Colloid Surface A*. 2010; 369(3):27-33. - Google Search'. Accessed: Oct. 31, 2023
 22. N. Durán, P. D. Marcato, A. Ingle, A. Gade, and M. Rai, 'Fungi-mediated synthesis of silver nanoparticles: Characterization processes and applications', *Progress in Mycology*, pp. 425–449, 2010, doi: 10.1007/978-90-481-3713-8_16.
 23. M. Guilger-Casagrande and R. de Lima, 'Synthesis of Silver Nanoparticles Mediated by Fungi: A Review', *Front BioengBiotechnol*, vol. 7, Oct. 2019, doi: 10.3389/FBIOE.2019.00287.
 24. D. Biradar, K. Lingappa, A. D.-J. of Ecobiotechnology, and undefined 2012, 'Antibacterial activity of nano gold particles synthesized by *Bacillus Sps*', *core.ac.ukDBiradar, K Lingappa, A DayanandJournal of Ecobiotechnology, 2012•core.ac.uk*, Accessed: Oct. 19, 2023. [Online]. Available: <https://core.ac.uk/download/pdf/236007210.pdf>
 25. 'M Ramya, M.S.S., "Green Synthesis of Silver Nanoparticles". *Int. J. Pharm. Med. & Bio. Sc*. 2012; 1. - Google Search'. Accessed: Oct. 31, 2023.
 26. H. Chopra et al., 'Green Metallic Nanoparticles: Biosynthesis to Applications', *Front BioengBiotechnol*, vol. 10, Apr. 2022, doi: 10.3389/FBIOE.2022.874742.





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27. S. S. D. Jini, 'silver nanoparticles in antidiabetic activity - Google Scholar', Department of Chemical Engineering, Hindustan Institute of Technology and Science, Padur, Kelambakkam, Chennai, Tamil Nadu, India. Accessed: Oct. 31, 2023. [Online]. Available: https://scholar.google.com/scholar?hl=en&as_sdt=0%2C5&q=silver+nanoparticles+in+an+antidiabetic+activity&btnG=
28. K. Balanet *et al.*, 'Antidiabetic activity of silver nanoparticles from green synthesis using *Lonicera japonica* leaf extract', *pubs.rsc.org*, Accessed: Oct. 31, 2023. [Online]. Available: <https://pubs.rsc.org/en/content/articlehtml/2016/ra/c5ra24391b>
29. D. Jini, S. S.-M. T. Proceedings, and undefined 2020, 'Green synthesis of silver nanoparticles from *Allium cepa* and its in vitro antidiabetic activity', *Elsevier*, Accessed: Oct. 31, 2023. [Online]. Available: <https://www.sciencedirect.com/science/article/pii/S2214785319328676>
30. K. Shanker, G. Mohan, ... M. H.-P., and undefined 2017, 'characterization, in vitro antidiabetic activity, and investigational acute toxicity studies of some herbal-mediated silver nanoparticles on animal models', *ncbi.nlm.nih.gov*, Accessed: Oct. 31, 2023. [Online]. Available: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5307906/>
31. S. Thirumal, T. S.-Int. j. botany stud, and undefined 2021, 'Synthesis of silver nanoparticles using *Cassia auriculata* leaves extracts and their potential antidiabetic activity', *researchgate.net*, Accessed: Oct. 31, 2023.
32. S. T. Galatageet *et al.*, 'Silver Nanoparticles: Properties, Synthesis, Characterization, Applications and Future Trends', *Silver Micro-Nanoparticles - Properties, Synthesis, Characterization, and Applications*, Sep. 2021, doi: 10.5772/INTECHOPEN.99173. '9. Pharmacologic Approaches to Glycemic Treatment: Standards of Medical Care in Diabetes—2019', *Diabetes Care*, vol. 42, pp. S90–S102, Jan. 2018, doi: 10.2337/DC19S009.
33. N. Chi, M. Narayanan, ... A. C.-E., and undefined 2022, 'Fabrication, characterization, antiinflammatory, and anti-diabetic activity of silver nanoparticles synthesized from *Azadirachta indica* kernel aqueous extract', *Elsevier*, Accessed: Oct. 31, 2023. [Online]. Available: <https://www.sciencedirect.com/science/article/pii/S0013935122000111>
34. A. Alkaladi, A. Abdelazim, M. A.-I. journal of molecular, and undefined 2014, 'Antidiabetic activity of zinc oxide and silver nanoparticles on streptozotocin-induced diabetic rats', *mdpi.com*, vol. 15, 2014, doi: 10.3390/ijms15022015.
35. A. Sengottaiyanet *et al.*, 'Synthesis and characterization of *Solanum nigrum*-mediated silver nanoparticles and its protective effect on alloxan-induced diabetic rats', *J Nanostructure Chem*, vol. 6, no. 1, pp. 41–48, Mar. 2016, doi: 10.1007/S40097-015-0178-6.
36. G. D. Sarataleet *et al.*, 'Anti-diabetic Potential of Silver Nanoparticles Synthesized with *Argyrea nervosa* Leaf Extract High Synergistic Antibacterial Activity with Standard Antibiotics Against Foodborne Bacteria', *J ClustSci*, vol. 28, no. 3, pp. 1709–1727, May 2017, doi: 10.1007/S10876-017-1179-Z.
37. R. G. Saratale, H. S. Shin, G. Kumar, G. Benelli, D. S. Kim, and G. D. Saratale, 'Exploiting antidiabetic activity of silver nanoparticles synthesized using *punicagranatum* leaves and anticancer potential against human liver cancer cells (HepG2)', *Artif Cells NanomedBiotechnol*, vol. 46, no. 1, pp. 211–222, Jun. 2018, doi: 10.1080/21691401.2017.1337031.
38. R. Perumalsamy, L. K.-A. B. and Biotechnology, and undefined 2022, 'Anti-Diabetic Activity of Silver Nanoparticles Synthesized from the Hydroethanolic Extract of *Myristica fragrans* Seeds', *Springer*, vol. 194, no. 3, pp. 1136–1148, Mar. 2010, doi: 10.1007/s12010-022-03825-8.
39. T. Mishra, 'Silver Nanotechnology for wound healing', *International Journal of Pharmaceutical Research and Applications*, vol. 8, p. 1155, doi: 10.35629/7781080311551163.
40. J. Tian *et al.*, 'Topical Delivery of Silver Nanoparticles Promotes Wound Healing', *ChemMedChem*, vol. 2, no. 1, pp. 129–136, Jan. 2007, doi: 10.1002/CMDC.200600171.
41. A. Kaler, A. Mittal, M. Katariya, ... H. H.-J. of nanoparticle, and undefined 2014, 'An investigation of in vivo wound healing activity of biologically synthesized silver nanoparticles', *Springer*, Accessed: Oct. 31, 2023. [Online]. Available: <https://link.springer.com/article/10.1007/s11051-014-2605-x> silver nanoparticles in wound healing activity - Google Scholar'. Accessed: Oct. 31, 2023. [Online]. Available: https://scholar.google.com/scholar?hl=en&as_sdt=0%2C5&q=silver+nanoparticles+in+wound+healing+activity&oq=





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42. S. Percival, L. Suleman, ... C. V.-J. of medical, and undefined 2015, 'Healthcare-associated infections, medical devices and biofilms: risk, tolerance and control', *microbiologyresearch.org* SL Percival, L Suleman, C Vuotto, G Donelli *Journal of medical microbiology*, 2015 • *microbiologyresearch.org*, vol. 64, no. 4, pp. 323–334, 2015, doi: 10.1099/jmm.0.000032.
43. P. H. Wang, B. S. Huang, H. C. Horng, C. C. Yeh, and Y. J. Chen, 'Wound healing', *J Chin Med Assoc*, vol. 81, no. 2, pp. 94–101, Feb. 2018, doi: 10.1016/J.JCMA.2017.11.002.
44. M. Rybka, Ł. Mazurek, and M. Konop, 'Beneficial Effect of Wound Dressings Containing Silver and Silver Nanoparticles in Wound Healing—From Experimental Studies to Clinical Practice', *Life* 2023, Vol. 13, Page 69, vol. 13, no. 1, p. 69, Dec. 2022, doi: 10.3390/LIFE13010069.
45. E. Alarcon, M. Griffith, K. U.-S. I. Publishing. doi, and undefined 2015, 'Silver nanoparticle applications', *Springer*, doi: 10.1007/978-3-319-11262-6_2.
46. A. K. Chatterjee, R. Chakraborty, and T. Basu, 'Mechanism of antibacterial activity of copper nanoparticles', *Nanotechnology*, vol. 25, no. 13, Apr. 2014, doi: 10.1088/09574484/25/13/135101.
47. A. Kaleret *et al.*, 'An investigation of in vivo wound healing activity of biologically synthesized silver nanoparticles', *Journal of Nanoparticle Research*, vol. 16, no. 9, 2014, doi: 10.1007/S11051-014-2605-X.
48. H. S. A. Al-Shmgani, W. H. Mohammed, G. M. Sulaiman, and A. H. Saadoon, 'Biosynthesis of silver nanoparticles from Catharanthus roseus leaf extract and assessing their antioxidant, antimicrobial, and wound-healing activities', *Artif Cells NanomedBiotechnol*, vol. 45, no. 6, pp. 1234–1240, Aug. 2017, doi: 10.1080/21691401.2016.1220950.
49. T. Gunasekaran, T. Nigusse, and M. D. Dhanaraju, 'Silver nanoparticles as real topical bullets for wound healing', *J Am Coll Clin Wound Spec*, vol. 3, no. 4, pp. 82–96, Dec. 2012, doi: 10.1016/J.JCWS.2012.05.001.
50. A. Abdellatif, N. Tolba, ... O. A. R.-S. P., and undefined 2022, 'Green synthesis of silver nanoparticles for enhancing wound healing activity in rats', *academia.edu*, Accessed: Oct. 31, 2023. [Online]. Available: https://www.academia.edu/download/85819014/1_s2.0_S1319016422000536_main.pdf
51. M. Maghimaa, S. A.-J. of P. and P. B, and undefined 2020, 'Green synthesis of silver nanoparticles from Curcuma longa L. and coating on the cotton fabrics for antimicrobial applications and wound healing activity', *Elsevier*, Accessed: Oct. 31, 2023. [Online]. Available: <https://www.sciencedirect.com/science/article/pii/S1011134419317695> [54] C. Rigoet *et al.*, 'Active silver nanoparticles for wound healing', *mdpi.com*, vol. 14, pp. 4817– 4840, 2013, doi: 10.3390/ijms14034817. '(PDF) Silver nanoparticles and their antimicrobial applications'. Accessed: Oct. 28, 2023. [Online]. Available: https://www.researchgate.net/publication/329864767_Silver_nanoparticles_and_their_antimicrobial_applications
52. M. Skonieczna and D. Hudy, 'Biological Activity of Silver Nanoparticles and Their Applications in Anticancer Therapy', *Silver Nanoparticles - Fabrication, Characterization and Applications*, Jul. 2018, doi: 10.5772/INTECHOPEN.77075.
53. P. R. More, S. Pandit, A. De Filippis, G. Franci, I. Mijakovic, and M. Galdiero, 'Silver Nanoparticles: Bactericidal and Mechanistic Approach against Drug Resistant Pathogens', *Microorganisms* 2023, Vol. 11, Page 369, vol. 11, no. 2, p. 369, Feb. 2023, doi: 10.3390/MICROORGANISMS11020369.
54. I. Sondi, B. S.-S.-J. of colloid and interface science, and undefined 2004, 'Silver nanoparticles as antimicrobial agent: a case study on E. coli as a model for Gram-negative bacteria', *Elsevier*, Accessed: Oct. 29, 2023. [Online]. Available: <https://www.sciencedirect.com/science/article/pii/S0021979704001638>
55. J. L. Elechiguerra *et al.*, 'Interaction of silver nanoparticles with HIV-1', *J Nanobiotechnology*, vol. 3, Jun. 2005, doi: 10.1186/1477-3155-3-6.
56. P. Gong *et al.*, 'Preparation and antibacterial activity of Fe₃O₄@Ag nanoparticles', *Nanotechnology*, vol. 18, no. 28, Jul. 2007, doi: 10.1088/0957-4484/18/28/285604.
57. G. A. Martínez-Castañón, N. Niño-Martínez, F. Martínez-Gutierrez, J. R. MartínezMendoza, and F. Ruiz, 'Synthesis and antibacterial activity of silver nanoparticles with different sizes', *Journal of Nanoparticle Research*, vol. 10, no. 8, pp. 1343–1348, 2008, doi: 10.1007/S11051-008-9428-6.
58. V. Q. N. and A.-T. L. QuangHuy Tran1, 'Silver nanoparticles: synthesis, properties, toxicology, applications and perspectives', *Vietnam Academy of Science & Technology*. Accessed: Oct. 30, 2023.





Sharmila Naykar and Ramdas

59. P. K. Dubas .T .S, 'S. T. Dubas, P. Kumlangdudsana, P. Potiyaraj, ColloidsSurf. A: Physicochem.Eng. Asp.2006,289, 105 - Google Search', <http://doi.org/10.1016/j.colsurfa>. Accessed: Oct. 30, 2023
60. C. Beer, R. Foldbjerg, Y. Hayashi, D. S.-T. letters, and undefined 2012, 'Toxicity of silver nanoparticles – nanoparticle or silver ion?', *Elsevier*, Accessed: Oct. 31, 2023. [Online]. Available: <https://www.sciencedirect.com/science/article/pii/S037842741101602X>
61. M. Ahamed, M. AlSalhi, M. S.-C. chimicaacta, and undefined 2010, 'Silver nanoparticle applications and human health', *Elsevier*, Accessed: Oct. 29, 2023. [Online]. Available: <https://www.sciencedirect.com/science/article/pii/S0009898110005139>
62. 'Yu-Guo Yuan. "Silver nanoparticles potentiates cytotoxicity and apoptotic potential of camptothecin in human cervical cancer cells" Oxidative Medicine and Cellular Longevity. 2018;1-22. - Google Search'. Accessed: Oct. 31, 2023
63. M. Rai, A. Yadav, and A. Gade, 'Silver nanoparticles as a new generation of antimicrobials', *BiotechnolAdv*, vol. 27, no. 1, pp. 76–83, Jan. 2009, doi: 10.1016/j.biotechadv.2008.09.002.
64. K. Kulthong, S. Srisung, K. Boonpavanitchakul, W. Kangwansupamonkon, and R. Maniratanachote, 'Determination of silver nanoparticle release from antibacterial fabrics into artificial sweat', *Part FibreToxicol*, vol. 7, Apr. 2010, doi: 10.1186/1743-8977-7-8.
65. A. O. Oladipo, S. L. Lebelo, and T. A. M. Msagati, 'Nanocarrier design–function relationship: The prodigious role of properties in regulating biocompatibility for drug delivery applications', *ChemBiol Interact*, vol. 377, May 2023, doi: 10.1016/j.cbi.2023.110466.
66. 'E.-J. Park, J. Yi, Y. Kim, K. Choi, K. Park, Toxicol. InVitro 2010,24, 872 - Google Search'. Accessed: Oct. 30, 2023 'K. Kawata, M. Osawa, S. Okabe, Environ. Sci. Technol.2009,43, 604 - Google Search'. Accessed: Oct. 30, 2023
67. P. O. M. H. D. A. D. J. H. H. A. Toxicol. R. Foldbjerg, 'PVP-coated silver nanoparticles and silver ions induce reactive oxygen species, apoptosis and necrosis in THP-1 monocytes', *ToxicolLett*. Accessed: Oct. 30, 2023
68. S. J. O. N. A. M.-R. Meghan E Samberg 1, 'Evaluation of silver nanoparticle toxicity in skin in vivo and keratinocytes in vitro', *Environ Health Perspect* . . Accessed: Oct. 30, 2023.
69. C. Jelenko, 'Silver nitrate resistant E. coli: report of case', *Ann Surg*, vol. 170, no. 2, pp. 296–299, 1969, doi: 10.1097/00000658-196908000-00021.
70. G. Larkin Mchugh, R. C. Moellering, C. C. Hopkins, and M. N. Swartz, 'Salmonella typhimurium resistant to silver nitrate, chloramphenicol, and ampicillin', *Lancet*, vol. 1, no. 7901, pp. 235–240, Feb. 1975, doi: 10.1016/S0140-6736(75)91138-1.
71. M. A. B. L. S. S. I. S. Ahmed, 'Biosynthesis of gold nanoparticles: A green approach', Bio/polymers Research Laboratory, Department of Chemistry, JamiaMilliaIslamia (A Central University), New Delhi 110025, India b Department of Chemistry, Faculty of Mathematics and Natural Sciences, University of Bengkulu, Indonesia. Accessed: Oct. 30, 2023
72. K. I. b, N. W. b, M. T. Takesh Tsuji a, 'Preparation of silver nanoparticles by laser ablation in solution: influence of laser wavelength on particle size', Institute of Advanced Material Study, Kyushu University, Kasuga-shi, Fukuoka 816-8580, Japan. Accessed: Oct. 30, 2023.
73. M. Stensberg, Q. Wei, ... E. M.-, and undefined 2011, 'Toxicological studies on silver nanoparticles: challenges and opportunities in assessment, monitoring and imaging', *Future Medicine*, Accessed: Oct. 31, 2023. [Online]. Available: <https://www.futuremedicine.com/doi/abs/10.2217/nnm.11.78>
74. M. C. Stensberg, Q. Wei, E. S. McLamore, D. M. Porterfield, A. Wei, and M. S. Sepúlveda, 'Toxicological studies on silver nanoparticles: Challenges and opportunities in assessment, monitoring and imaging', *Nanomedicine*, vol. 6, no. 5, pp. 879–898, Jul. 2011, doi: 10.2217/NNM.11.78.
75. P. Prasher, M. Singh, and H. Mudila, 'Silver nanoparticles as antimicrobial therapeutics: current perspectives and future challenges', *3 Biotech*, vol. 8, no. 10, Oct. 2018, doi: 10.1007/S13205-018-1436-3.
76. A. Syafiuddin, Salmiati, M. R. Salim, A. Beng Hong Kueh, T. Hadibarata, and H. Nur, 'A Review of Silver Nanoparticles: Research Trends, Global Consumption, Synthesis, Properties, and Future Challenges', *Journal of the Chinese Chemical Society*, vol. 64, no. 7, pp. 732–756, Jul. 2017, doi: 10.1002/JCCS.201700067.





Sharmila Naykar and Ramdas

77. J. Chawla, D. Singh, B. Sundaram, and A. Kumar, 'Identifying Challenges in Assessing Risks of Exposures of Silver Nanoparticles', *Expo Health*, vol. 10, no. 1, pp. 61–75, Mar. 2018, doi: 10.1007/S12403-017-0245-Y.

78. S. M. R. S. A. B. H. K. T. H. H. N. AchmadSyafiuddin, 'silver nanoparticles of future challenges - Google Scholar', google scholar. Accessed: Oct. 31, 2023. [Online]. Available: https://scholar.google.com/scholar?hl=en&as_sdt=0%2C5&q=silver+nanoparticles+of+future+challenges&btnG=

79. A. Istiqola, A. S.-J. of the C. Chemical, and undefined 2020, 'A review of silver nanoparticles in food packaging technologies: Regulation, methods, properties, migration, and future challenges', *Wiley Online Library*, vol. 67, no. 11, pp. 1942–1956, Nov. 2020, doi: 10.1002/jccs.202000179.

80. M. C. Stensberg, Q. Wei, E. S. McLamore, D. M. Porterfield, A. Wei, and M. S. Sepúlveda,

81. 'Toxicological studies on silver nanoparticles: Challenges and opportunities in assessment, monitoring and imaging', *Nanomedicine*, vol. 6, no. 5, pp. 879–898, Jul. 2011, doi: 10.2217/NNM.11.78/ASSET/IMAGES/MEDIUM/FIGURE8.GIF.

82. P. Prasher, M. Singh, H. M.-3 Biotech, and undefined 2018, 'Silver nanoparticles as antimicrobial therapeutics: current perspectives and future challenges', *Springer*, Accessed: Oct. 31, 2023. [Online]. Available: <https://link.springer.com/article/10.1007/s13205-018-1436-3>

83. A. Syafiuddin, undefined Salmiati, ... M. S.-J. of the, and undefined 2017, 'A review of silver nanoparticles: research trends, global consumption, synthesis, properties, and future challenges', *Wiley Online Library*, Accessed: Oct. 31, 2023. [Online]. Available: <https://onlinelibrary.wiley.com/doi/abs/10.1002/jccs.201700067>

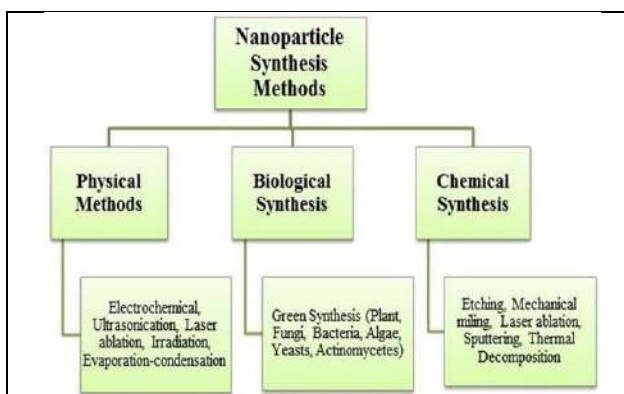


Fig 1: Methods of silver Nanoparticles

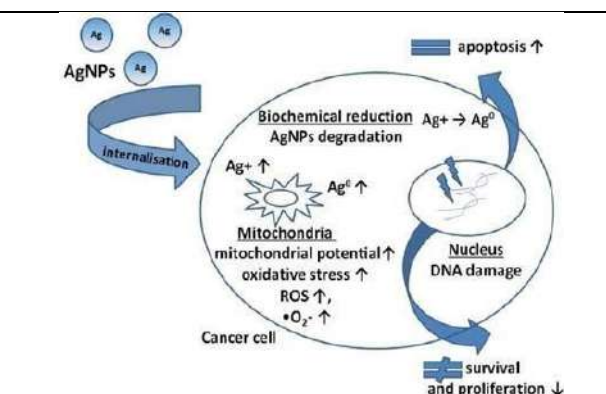


Fig 2: Mechanism of action of Anticancer activity of silver nanoparticles





Comparison of Promptly Effect of Mulligan Bent Leg Raise Technique and Suboccipital Muscle Inhibition Technique in Attendant with Hamstring Tightness : An Experimental Study

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ABSTRACT

The normal length of hamstring is important in human posture and in the efficiency of daily human movements such as walking and running. Poor hamstring flexibility also impact on normal biomechanical patterns affecting balance, functional performance and sport performance and leading to impaired mobility, postural deviation, pain and increased of injury. To compare the promptly effect of Mulligan bent leg raise technique and Sub occipital muscle inhibition technique in attendant with hamstring tightness.

Keywords: Hamstring flexibility, Mulligan BLRT , SMT, SRT

INTRODUCTION

Muscular flexibility is an important feature of proper human function in the musculoskeletal system. Limited flexibility has been found to increase the risk of overuse injuries and have a major impact on a person's level of function. Muscle tightness is usually cited as an inherent risk factor for muscle injury. It's been hypothesised that a lack of flexibility is a risk factor for hamstring injuries The suboccipital muscle inhibition technique (SMIT) is associated with changes in body flexibility. It increases the range of motion (ROM) in patients with several pathologic





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conditions . It increased ROM of the hip and knee joints in patients with hamstring shorting There are positive outcome of this research and many other research has been conducted for this but comparison of this to technique on healthy individual in both male and female had not been conducted As a result, the purpose of this study was to assess the promptly effects of the Mulligan Bent Leg Raise technique vs the suboccipital muscle inhibition approach on hamstring tightness.

MATERIALS AND METHODOLOGY

RESEARCH DESIGN: An Experimental Study

ETHICAL APPROVAL: This study was approved by institutional ethical committee.

STUDY POPULATION: Study has been conducted in residential areas and colleges of Ahmedabad, Gujarat.

SELECTION CRITERIA

INCLUSION CRITERIA

Those who are willing to participate

Age 25 to 40 years

Gender- male and female

Popliteal angle test (PAT) measure is less than 125° 3.4.2

EXCLUSION CRITERIA

Fracture in lower extremity

Patient having low back pain

Herniated disc or lumbar protrusion

Tendon injury of hamstring

Pregnant women

Major psychological stress

Symptoms in lower extremity

SAMPLE DESIGN: Sample random sampling **SAMPLE SIZE:** 52

Group A – 26

Group B – 26

STUDY DURATION: Study was conducted for 2 months.

MATERIALS

Consent Form and Assessment Form

Universal goniometer (360°)

Pencil, pen

Sit and reach box

Watch

INTERVENTION

Group A: [Experimental group 1] received Mulligan bent leg raise technique.

Group B: [Experimental group 2] received Suboccipital muscle inhibition technique.

All of the study attendant were told to keep doing what they were doing and to stay away from alternative forms of treatment. During the intervention phase, subjects were not allowed to use any other sort of electrotherapy or other methods (steroids, acupuncture, or tapping). Attendant were not required to do any type of stretching.





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GROUP A: MULLIGAN BENT LEG RAISE TECHNIQUE

The BLR approach consists of moderate isometric hamstring stretching in specific directions in increasingly larger positions of hip flexion, with the expected benefits being increased hamstring flexibility and active knee extension range of motion. The procedure for performing BLR was as follows: The participant was laying supine on a high couch, with the investigator in a walk stand position to the side of the stretched leg. The hip and knee of the stretched side were bent at 90-90 degrees. The participant's flexed knee was put over his shoulder, with the popliteal fossa lying on his shoulder. At the lower end of the femur, a distraction (longitudinal traction force along the long axis of the femur) was applied, and the participant was requested to push the investigator's shoulder with his or her leg before voluntarily relaxing. The investigator pulled the bent leg up as far as feasible in the direction of the shoulder on the same side in a pain-free range at this stage of relaxation. This stretch was held for 5-10 seconds before being released. If the pain or limitation went away, the hip was flexed even more. If there was any pain throughout the process, the direction of the leg elevation was changed medially or laterally if necessary. The practise was continued until the participant's knee was beyond the therapist's shoulder. The contralateral leg was left unrestricted and free to move around. The position was kept for 10 seconds at the end of the range before the limb was returned to its neutral position. Throughout the process, the traction was maintained.

GROUP B: SUBOCCIPITAL MUSCLE INHIBITION TECHNIQUE.

With the patient supine, the therapist sat at the head of the table and places the palms of hands under the subject's head, pads of therapist's fingers on the projection of the posterior arch of the atlas which is palpated between the external occipital protuberance and spinous process of axis vertebra. The therapist locates the gap between the occipital condyles and the spinal process of the second cervical vertebra using the middle and ring fingers of both hands. The therapist then places the base of the cranium on hands with the metacarpophalangeal joints in 90° flexion. Upward and toward the therapist, pressure was applied. The pressure was maintained for 2 minutes until tissue relaxation had been achieved. During the SMI technique, the subject is asked to keep his eyes closed to avoid eye movements affecting the suboccipital muscle tone.

PROCEDURE

Assessment

Study was approved by ethical committee. Healthy individuals from various residential area of Ahmedabad and colleges were assessed as per the inclusion and exclusion criteria. They were briefly stated the nature of study and intervention and written consent was taken from them. Demographic data and baseline values of the study were taken prior of study. The subjects were divided into two groups via lottery method.

ASSESSMENT FOR HAMSTRING FLEXIBILITY

PAT test:⁽⁶⁵⁾

The subjects were in supine position with hip and knee flexed 90°

The testing was done on the right lower extremity and subsequently on the left lower extremity and the pelvis was strapped down to the table for stabilization. The fulcrum of the goniometer was centered over the lateral condyle of the femur. The proximal arm was aligned with the long axis of femur using greater trochanter as a reference. The distal arm was aligned with the lower leg using the lateral malleolus as a reference. The subject was then asked to extend the lower extremity as far as possible until a mild stretch was felt.

SIT AND REACH TEST (SRT)

This exam requires you to sit on the floor with your legs spread out straight front and your shoes removed. Shoes should be removed. The soles of feet were placed flat against the box. Both knees were locked and pressed flat to the floor. With the palms facing downwards, and the hands on top of each other or side by side, the subject reaches forward along the measuring line as far as possible. Ensure that the hands remain at same level, not one reaching further forward than the other, hold that position for at one-two seconds while the distance is recorded.





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RESULTS

The goal of this study was to see if the Mulligan Bent Leg Raise technique affected hamstring flexibility in people who had hamstring tightness. The study involved 52 attendant. The statistical software SPSS 20 version was used to examine the data. Data was checked for normal distribution before statistical tests were run. All outcome measures were analysed using suitable statistical tests at baseline and promptly after therapy. In this investigation, the study's power was kept at 80%, while the threshold of significance was retained at 95%. Changes in outcome measures were examined both within and across groups. The outcome measurement were hamstring flexibility measured on popliteal angle test measured by GONIOMETER and sit and reach test by sit and reach box. To check the normality distribution of data Shapiro-wilk test is used

DISCUSSIONS

Mulligan bent leg lift technique and Suboccipital muscular inhibition technique exhibited statistically significant improvement, according to the findings of this study. It was established that both techniques are beneficial in improving hamstring flexibility in people who have tight hamstrings. When experimental groups 1 and 2 were compared, it was discovered that the Mulligan bending leg raise technique (BLRT) is more effective on SRT than the Sub occipital muscular inhibition technique (SOMIT) (SMT). The Mulligan bent leg lift technique breaks up scar tissue adhesions, allowing the muscle to fully extend and recover suppleness for functional use. According to Vicenzino B., Paungmali A., and Teys P., there are a growing number of papers endorsing Mulligan's mobilisation with movement approaches as having therapeutically beneficial effects. The most frequent report effect is that of an PROMPTLY and substantial pain reduction accompanied by improved function.²⁸ The findings of our study are backed up by Oves Patni et al, who found that the BLR resulted in a difference of 3.7 and 4 cm in pre and posttest measures when observed within groups.²⁹ The BLR approach may improve SLR range by mobilising unpleasant, sensitive nerve tissues, which is analogous to the "slider" effects^{16,17}. However, it's unclear that this is the main therapeutic advantage; just one-third of the attendant in a similar LBP group with SLR limitation displayed evidence of sensitive brain tissue¹⁸. Another advantage of the BLR approach could be an increase in hamstring stretch tolerance. Goeken and Hof found that enhanced SLR range is mediated by greater hip flexion and hamstring length, rather than increased hamstring viscoelastic characteristics, after stretching. Because the superficial back line was relaxed through relaxation of the suboccipital muscles, the suboccipital muscle inhibition approach could promote hamstring flexibility³¹. The "proprioceptor monitors" that contribute greatly to head posture regulation are the suboccipital muscles, which have the most muscle spindles in the human body¹⁶). Among them, in particular, the rectus capitis posterior minor muscle, which has 36 muscle spindles per gram, is known to contribute greatly to regulation of posture and the degree of tension³²) According to Robert Scliep⁷ in 1996^{16,17}, studies on the effect of SMI on hamstring flexibility also resulted in improved flexibility due to the connection to the dura mater, postural control, and myofascial chain connection, which also validates the findings of this study³³.³⁴ According to the results of our research, the Sub occipital muscle inhibition approach resulted in a difference of 1 to 1.5 cm in pre and post sit and reach test measures when measured among groups

CONCLUSIONS

The results of this study show that both the Mulligan bent leg lift technique and the Suboccipital muscle inhibition technique are successful in improving hamstring flexibility quickly. Mulligan bent leg raise technique improved hamstring flexibility more than Suboccipital muscle inhibition approach in attendant with hamstring tightness

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REFERENCES

1. Nagarwal A.K, ZutshiK, Ramcs.,Zafar R. Improvement of hamstring flexibility: A comparison between two PNF stretching techniques. International journal of sports science and engineering 2010; vol. 4:25- 33.
2. Glen M. De Pino,William G. Webright,Brent L. Arnold. Duration of maintained hamstring flexibility after cessation of an acute static stretching protocol. Journal of athletic training 2000;35(1);56-59.
3. Kieran O'Sullivan, ElaineMurray,David Sainsbury. The effect of warm-up, static stretching and dynamic stretching on hamstring flexibility in previously injured subjects. BMC Musculoskeletal Disorders 2009;vol. 10:37.
4. Carolyn Kisner , Lynn Allen Colby : Therapeutic exercise : Foundation and Techniques : 1996; 144, 174 – 175.
5. 2. Harty James, Softe Karen, O'toole Gary; Stephens Michael M:The Role Of hamstring tightness in plantar fasciitis. Foot and ankle international. ISSN 1071-1007, 2005, Vol. 26, No. 12. PP 1089-1092.
6. 3. Cooney KM, Sanders JO, Concha MC, Buczek EL: Novel biomechanics demonstrate gait dysfunction due to hamstring tightness. Clin. Biomech. (Bristol, Avon) 2006 Jan; 21 (1) 59 – 66.
7. Mulligan BR. Other spinal therapies. In: Manual therapy: "nags","snags", "mwms" etc. 4th. Wellington: Plane View Services; 1999.p. 68–8.
8. Kaltenborn FM: Mobilisation of the Extremity Joints. 4th Edn.Orthopaedic Physical Therapy Products, USA. 1989.
9. Toby Hall, Hardt S, Schafer A, Wallin A. Mulligan bent leg raise technique-a preliminary randomized trial of PROMPTLY effects after a single intervention. Manual therapy 2006; 130-135
10. Aparicio EQ, Quirante LB, Blanco CR, et al.: PROMPTLY effects of the suboccipital muscle inhibition technique in subjects with short hamstring
11. syndrome. J Manipulative PhysiolTher, 2009, 32: 262–269. [Medline] [CrossRef] Hallgren RC, Greenman PE, Rechten JJ: Atrophy of suboccipital muscles in patients with chronic pain: a pilot study. J Am Osteopath Assoc, 1994, 94: 1032–1038. [Medline]
12. McPartland JM, Brodeur RR, Hallgren RC: Chronic neck pain, standing balance, and suboccipital muscle atrophy—a pilot study. J Manipulative PhysiolTher, 1997, 20: 24–29. [Medline]
13. Hack GD, Koritzer RT, Robinson WL, et al.: Anatomic relation between the rectus capitis posterior minor muscle and the dura mater. Spine, 1995, 20: 2484–2486. [Medline] [CrossRef] Myers TW: Anatomy trains. Edinburgh: Churchill Livingstone, 2005, pp 97– 101.
14. Akinpelu A O, Bakare U. Influence of age on hamstring tightness in apparently healthy Nigerians. Journal of Nigeria Society of Physiotherapy, 2009 jul 22;15(2):35-41.
15. Mayorga-Vega D, Merino-Marban R, Real J, Viciano J; A physical education basef stretching program performed once a week also improves hamstring flexibility in school children: a cluster randomized control trial;2015;32(4):1715-21.
16. Koulouris G, Connell D. Hamstring muscle complex: an imaging review.radiographics .2005 May;25(3):571-86.
17. Ahmed AR, Samhan AF. Short term effect of neurodynamic stretching and static stretching techniques on hamstring muscle flexibility in health male subjects.Int J Med Res Heal Sci. 2016 Jan 1;5(5):36-41
18. Vijay Kage,Rakhi Ratnam,et al (2014) conductedstudy "PROMPTLYeffectofactiveverleasetechniqueversus MulliganBent Leg Raise in subjects with hamstring tightness: a randomized clinical trial"
19. Oves Patnil , Saravanan M2 , Aliya Shaikh3 , Ankita Juneja3 , Nazrana Shaikh3 , Ruchi Patel3,et al (2013)conducted study on "Effect of single bout of passive stretching and Mulligan's Bent Leg Raise (BLR) on Hamstring flexibility in young adults with asymptomatic bilateral Hamstring tightness"





Jaynesh Vandra et al.,

20. Tejashree bhoir1 ,deepak b. Anap2,et al (2016) PROMPTLY effect of mulligan bent leg raise technique versus self myofacial release on hamstring tightness in young adults-a randomized controltrial
21. Sung-Hak Cho, PhD, PT1), Soo-Han Kim, PhD, PT2), Du-Jin Park, PhD, PT2), et al (2016) conducted study on “The comparison of the PROMPTLY effects of application of the suboccipital muscle inhibition and self-myofascialrelease techniques in the suboccipital region on short hamstring”
22. Sonal Balani1 , Chitra Kataria2, et al (2015) conducted study on “Comparing Effectiveness of Suboccipital Muscle Energy Technique Alone, Passive Hamstring Stretching Technique Alone and Combination of both forImproving Hamstring Muscle Flexibility in Healthy Collegiate Subjects “
23. Dr Rasika Pansel1* , Dr Ujwal Yeole2 , Shubhada Trivedi3 , Dr Pournima Pawar, et al (2018) conducted study on “To study the effect of Suboccipital Muscle Inhibition and Neural Flossing Techniques on Hamstring Flexibility inYoung Adults “
24. Pramod k. Jagtap1, shubhangi d. Mandale2, , et al (2015) conducted study on “ the effect of suboccipital muscle inhibition technique on hamstring tightness patients “
25. Vijay kage et al. (2017) conducted study “ effect of bowen technique
26. versus muscle energy technique on asymptomatic subject with hamstring tightness” used popliteal angle, sit and reach test and hand held dynamometer to measurehamstring tightness.
27. Koen A.P. Lemmink, et al. (2003) conducted study “The validity of the Sitand Reach test and the modified Sit and reach test in middle -aged to older Men and Women” Oves Patni, Saravanan M, Aliya Shaikh, Ankita Juneja, Nazrana Shaikh, Ruchi Patel. Effect of single bout of passive stretching and Mulligan's Bent Leg Raise (BLR) on Hamstring flexibility in young adults with asymptomatic bilateral Hamstring tightness; IOSR Journal of Dental and Medical Sciences (IOSR- JDMS).(Jul.- Aug. 2013), Volume 9, Issue 3 PP 13-17.
28. Goeken LN, Hof AL. Instrumental straightleg raising: results in patients. Archives of Physical Medicine and Rehabilitation 1994;75(4):470-7.
29. muscles31 Myers TW: Anatomy trains. Edinburgh: Churchill Livingstone,2005, pp 97-101..
30. McPartland JM, Brodeur RR: Rectus capitis posterior minor: a small but important suboccipital muscle. J Bodyw Mov Ther, 1999, 3: 30-35. [CrossRef] 17) Peck D, Buxton DF, Nitz A: A comparison of spindle concentrations in large and small muscles acting in parallel combinations. J Morphol, 1984, 180: 243-252

Table 1: MASTER CHART GROUP A (MULLIGAN BENT LEG RAISE TECHNIQUE)

SERIAL NO	AGE (YRS)	SEX	BMI (Kg/m2)	PAT (degree) (PRE)		PAT (degree) (POST)		SRT (cms) (PRE)	SRT (cms) (POST)
				RT	LT	RT	LT		
1	32	F	21.58	110	117	125	130	28	34
2	39	M	25.3	122	120	137	135	28	33
3	26	F	20.2	105	110	120	135	27	34
4	27	F	18	110	110	130	125	21	29
5	30	F	23.6	110	102	135	130	23	40
6	35	F	20.6	107	100	130	130	30	38
7	25	F	19	110	110	135	140	35	40
8	39	M	22.67	120	120	150	150	31	37
9	34	M	18.1	115	110	140	140	24	30
10	29	F	17.9	123	120	140	150	32	39
11	37	M	17.39	120	110	140	120	26	32
12	25	M	31.3	120	120	140	135	32	39
13	31	F	20.1	110	115	130	130	25	30
14	26	F	21.09	120	120	130	130	33	36
15	35	F	27	120	120	145	145	29	34
16	32	F	29	120	115	140	140	28	27





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17	36	F	20.07	115	115	125	125	27	35
18	30	F	23.04	113	113	130	130	21	25
19	36	F	17.77	115	115	130	130	23	26
20	26	F	25.18	102	110	115	120	26	32
21	25	F	24.45	105	115	120	125	32	36

Serial No	AGE (YRS)	SEX	BMI (Kg/m2)	PAT (degree) PRE		PAT (degree) POST		SRT (cms) PRE	SRT (cms) POST
23	27	F	20.8	124	122	130	130	26	35
24	31	M	23.9	116	114	125	125	30	38
25	32	F	25.3	107	110	117	120	24	30
26	29	M	25.5	118	120	130	130	25	31

GROUP B (SUB OCCIPITAL MUSCLE INHIBITION TECHNIQUE)

Serial NO	AGE (YRS)	SEX	BMI (Kg/m2)	PAT (DEGREE) (PRE)		PAT (degree) (POST)		SRT (cms) (PRE)	SRT (cms) (POST)
				RT	LT	RT	LT		
1	30	F	15.8	120	118	130	125	29	34.5
2	32	F	27.3	110	120	140	130	22	33
3	40	M	23.8	122	120	126	135	29	33
4	31	F	19.8	106	105	120	120	28	30
5	31	M	20.28	120	120	130	130	19	25
6	35	M	27.05	120	120	130	130	26	31
7	25	M	15.39	110	110	110	115	26	30
8	35	M	22.72	110	105	120	100	20	25
9	35	M	24	110	98	110	100	10	15
10	28	F	30.5	105	110	110	120	15	17
11	32	M	29.2	100	105	105	110	24	29
12	32	M	27	115	120	120	123	20	23
13	25	M	25.6	100	105	120	140	22	26
14	26	F	21.9	120	120	135	130	19	21
15	27	M	16.1	115	110	120	120	23	27
16	30	M	25.8	120	120	135	135	29	32
17	32	F	22.2	115	120	120	130	21	27
18	25	F	17.03	110	110	115	120	18	21
19	37	F	17	105	110	115	120	30	34
20	38	M	24.05	120	120	130	130	22	28
21	31	M	26.15	120	115	135	120	25	29
22	28	M	25.7	110	115	120	125	32	39
23	30	M	18.4	105	115	115	120	28	31
24	26	M	25.8	122	123	130	130	22	28
25	32	F	21.3	120	123	135	135	27	32
26	28	M	18.9	100	100	117	119	28	32





Cascade Multilevel Inverter for Grid-Connected Hybrid Solar and Wind Energy Systems

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ABSTRACT

In today's global energy landscape, power generation from renewable energy sources is becoming increasingly important. The primary reasons for this are the scarcity of fossil fuels and the environmental risks connected with existing energy producing technologies. The most popular grid-connected renewable energy systems are solar photovoltaic and moreover wind energy systems. This research provides a new system design for a hybrid solar and wind energy system that is grid-connected. This strategy enables these renewable energy sources to deliver the load simultaneously or separately, depending on availability. The suggested architecture employs a reformed five level inverter topology to convert DC voltage provided by renewable energy sources to AC voltage at 50 Hz. The use of a five-level inverter drops the level of total harmonic distortion (THD) in output voltage and assists in eliminating the need for bulk filters on the output side. A simulation study of the suggested technique has been carried out using MATLAB Simulink, and the outcomes of simulation have been presented.

Keywords: Total Harmonic Distortion, Wind energy system, Photovoltaic system, Renewable energy system.





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INTRODUCTION

Because of the scarcity of fossil fuels and the greenhouse impact, demand for renewable energy has skyrocketed in recent years. Solar and wind energy, among other renewable energy sources, have grown in popularity and demand as power electronics techniques have advanced. Photovoltaic sources are now widely used in a variety of applications because to their low maintenance and pollution-free nature. Over the last 20 years, solar-electric-energy consumption has grown at a constant rate of 20%-25% per year, owing primarily to lower costs and prices. The rising energy demand, higher expenses, the short-term availability of fossil fuels, and worldwide environmental pollution have sparked intense interest about renewable energy options. Aside from hydroelectric electricity, wind and solar are the predominant and efficient energy sources for fulfilling our power needs. Wind energy can provide massive amounts of power, but its availability is inconsistent. Solar electricity is accessible throughout the day, even though solar irradiance levels fluctuate due to incessant variations in the sun's shadows and intensity generated by many kinds of factors. In general, wind and sun power complement each other. Based on this, the hybrid photovoltaic and wind energy system delivers more consistent power than either system alone. Another advantage of the hybrid system is that it requires less battery storage because it operates more reliably than independent systems. This study also discusses the most important control and modulation methods established for this type of converter: multilevel sinusoidal PWM, selective elimination of harmonic in multilevel, and SVM. Special emphasis is given to the most recent and relevant uses of these converters, such as laminators, conveyor belts, and unified power-flow controllers. The need for an active front end on the input side of inverters supplying regenerative loads is also examined, as are the circuit layout alternatives. Finally, [1] addresses peripherally emerging sectors such as high-voltage, high-power devices and optical sensors, as well as other potential future development opportunities.

A review of various multilevel topologies and their applicability of grid connected solar systems. Several transformer-less photovoltaic systems with multilayer converters are examined in terms of component count and stress, system energy rating, and the impact of photovoltaic array earth capacitance [2]. Various topologies used for inverters are given, contrasted, and evaluated in terms of demand, longevity, component rating, and cost. Finally, various topologies are identified as the most promising for either single or multiple PV module applications [3]. Photovoltaic power is generated using solar panels made up of a number of solar cells containing photovoltaic material. Multilevel inverter architectures have been designed to address inadequacies in solid-state switching device ratings, allowing them to be used in high voltage electrical systems. The multilayer voltage source inverter's unique structure enables them to achieve high voltages with low harmonics without the usage of transformers. This results in unique power electronics topologies that are appropriate for Flexible AC Transmission Systems and specialized power applications [4]. A unique way for connecting renewable energy sources to the electric grid. Due to the rising power capability of available generation systems, a three-level three-phase neutral-point-clamped voltage-source inverter is chosen as the heart of the interface system [5]. The regulator employs a multivariable control law due to the system's inherent multivariable structure. To validate the suggested approach's good performance, a current source (playing the role of a generic renewable energy source) is connected to the grid via a three-level inverter [6]. A single-phase, five-level PV inverter designed for grid-connected installations, with a revolutionary PWM control technique. The switches' PWM signals were generated using two similar reference signals offset by the amplitude of the triangle carrier signal. The proposed system is validated through modeling and implemented as a prototype, and the experimental results are compared to those of a standard single-phase three-level grid-connected PWM inverter [7]. This arrangement enables the two sources to serve the load separately or concurrently, depending on the availability of the energy sources. This cuk-SEPIC fused converter's intrinsic design eliminates the need for extra input filters to filter out high frequency harmonics. This project discusses the closed loop mechanism of the CUK and SEPIC converters, and the simulation results are shown in [8].





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IMPLEMENTATION OF PROPOSED TECHNIQUE

DC-DC Converter

The converter of DC-DC with a large step-up voltage gain is utilized in a variety of applications, including high-intensity discharge lamp ballasts for automobile headlamps, fuel cell energy conversion systems, solar cell energy conversion systems, and battery backup systems for uninterruptable power supplies. In theory, a DC-DC Boost Converter can achieve a large step-up voltage gain while maintaining an exceptionally high duty ratio. In practice, the step-up voltage gain is restricted by power switches, rectifier diodes, and the equivalent resistance of capacitors and inductors. Fig. 1 depicts a high step-up DC-DC converter equipped with an filter for reduction of common mode electromagnetic interference and integrated coupling inductor. Here, a converter of step-up-flyback with a linked inductor and output voltage stacking is created. A high step-up converter with a connected inductor and a doubler of voltage approach on the stacking of output voltage is introduced. A boost converter with high step-up with numerous connected inductors at the output V_o .

Boost Converter

The principle of a Boost Converter consists of two distinct states:

- In the On-state, the switch S closes, increasing the inductor current.
- In the Off-state, the switch S is open, leaving just the flyback diode D, capacitor C, and load R_L for the inductor current to flow through it and Fig. 2 depicts the boost converter.

Continuous mode

When a boost converter functions in continuous mode, and also the current through the inductor I_L never reaches zero. Fig. 3 depicts typical waveforms of currents and voltages in a converter operating in this mode. The output voltage is computed as follows in the case of an ideal converter, which uses components with perfect behavior during steady-state operation.

During the On-state, the switch S is closed, causing the input voltage V_i to appear across the inductor, resulting in a change in current I_L flowing through the inductor during a time period t as defined by the formula:

$$\frac{\Delta I_L}{\Delta t} = \frac{V_i}{L}$$

The increase of I_L at the end of the On-state is

$$\Delta I_{L_{on}} = \frac{1}{L} \int_0^{DT} V_i dt = \frac{DT}{L} V_i$$

D is the duty cycle. It represents the fraction of the commutation period T during which the switch is ON. Therefore D ranges between 0 i.e., Switch is never on and 1 i.e., S is always on.

During the off-state, switch S is open, allowing inductor current to pass through the load. If we consider zero voltage drops in the diode and capacitor large enough to keep the voltage constant, the flow of I_L is:

$$V_i - V_o = L \frac{di_L}{dt}$$

Therefore, the variation of I_L during the Off-period is

$$\Delta I_{L_{off}} = \int_{DT}^T \frac{(V_i - V_o) dt}{L} = \frac{(V_i - V_o)(1-D)T}{L}$$

the duty cycle to be

$$D = 1 - \frac{V_i}{V_o}$$

The above expression demonstrates that the output voltage is always greater than the input voltage as the duty cycle progresses from 0 to 1, and that it grows with D , theoretically reaching infinity as D approaches 1. This converter is also named as a step-up converter.

Discontinuous mode

If the ripple content of the current is too large, the inductor may be entirely discharged before the end of the commutation cycle. This is usual with light loads. In this situation, the current through the inductor drops to zero for





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a portion of the period, as depicted in Fig.4. Although the change is modest, it has a more significant impact on the output voltage equation.

the gain of the output voltage can be expressed as follows:

$$\frac{V_o}{V_i} = 1 + \frac{V_i D^2 T}{2L I_o}$$

Cascaded H-Bridge Multilevel Inverter

Cascaded H-Bridge arrangement has lately gained popularity in high-power AC supply. A cascaded multilevel inverter consists of a sequence of H-bridge, or single-phase full bridge inverter units, in each of its three phases, as illustrated in Fig. 5. The ac terminal voltages of different level inverters are linked in series using various arrangements of the four switches, S1-S4. Each converter level can provide three different voltage outputs, namely +Vdc, -Vdc, and 0. The AC outputs of various full-bridge converters in the identical phase are linked in series, resulting in a synthetic voltage waveform which is the total of the converter outputs. The output-phase voltage levels numbering is determined differently than for other converters, such as diode clamped and flying capacitor. In this structure, the sum of output-phase voltage levels is denoted by $m = 2N+1$, where quantity of DC sources is N. A seven-level cascaded converter, for example, has three DC sources and three full bridge converters. Controlling the conducting angles at various converter levels can help to achieve the lowest harmonic distortion. Each H-bridge unit generates a quasi-square waveform by altering the positive and negative phase legs' switching timings. Five-level cascaded inverters will include two SDCS and two full-bridge cells. The sequence of switching of five-level cascaded inverter is deliberated in Table 1. Two complete Bridges are used and cascaded to each other. Switches S1, S2, S3, & S4 are from the upper H-bridge, while S5, S6, S7, and S8 are from the lower H-bridge. We can acquire five voltage levels by incorporating the suitable switching strategy. The switching table below shows how to get 5 levels using a symmetrical DC source.

PV/WIND BASED MULTILEVEL INVERTER FOR GRID CONNECTED SYSTEM

The maintenance of output voltage is constant, this study uses a boost converter in a solar photovoltaic system and a buck converter in a wind energy system. It enables battery charging with a steady voltage. A five-level inverter converts the battery's dc voltage to ac voltage and connects it to the grid. Multilevel inverters generate the necessary voltage by combining different levels of direct current voltages as inputs. As the number of levels increases, so does the output waveform, which transforms into a staircase wave with increasing steps. Thus, the output voltage approaches the ideal sinusoidal waveform. The precise significant benefits of employing multilayer inverter technique are lower power ratings for power devices and lower costs.. The main idea behind a multilayer converter is to increase the operating voltage by connecting power semiconductor switches with significantly lower voltage ratings than those used in a normal two-level inverter. These power switches are programmed such that a extreme number of voltage levels are generated at the output from numerous dc sources. A multilayer inverter has the advantage of being able to generate output voltages with extremely low THD, draw input current with low distortion, and work over the switching frequencies are a wide range from nominal reference frequency to utmost extreme frequency. The most common topologies of multilevel inverter are flying capacitor, diode clamped and cascaded H-bridge multilevel inverters. This paper proposes a redesigned multilayer inverter with fewer input DC switches and sources.

Proposed System Architecture

In order to confirm the battery charges smoothly, the voltage in the input should be constant. So the solar panel's output is sent through a boost converter to maintaining a consistent voltage. The wind generator employed here is a 230V AC induction generator. A rectifier converts the wind generator's output to DC, which is then supplied via a buck converter to maintain a steady output voltage. So the battery will be charged with both solar and wind energy. The battery output is supplied into a five-level multilevel inverter, which transforms it to alternating current (ac). Fig. 6 shows a block diagram of the proposed architecture. The voltage in between the each DC capacitor is $V_{DC} / 2$. The suggested inverter generates five levels of output voltage: V_{DC} , $V_{DC}/2$, 0, $-V_{DC}/2$, and $-V_{DC}$. An auxiliary circuit of





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four diodes and a switch is used to generate five voltage levels at the output. The proper switching sequence in this modified circuit produces five levels of output voltage.

RESULTS AND DISCUSSIONS

The MATLAB SIMULINK has been used to verifying the proposed inverter simulations. Table 1 illustrates the PWM switching approach employed in this paper. It is composed of reference signals and a triangle carrier signal. Both the reference signals are compared to the triangle carrier signal and PWM switching signals are generated for the inverter circuit's switches S1 through S5. It is worth noticing that one leg of the inverter switches at a fast rate equal to the frequency of the carrier signal, while the other leg switches at the fundamental frequency (50 Hz). The switch in auxiliary circuit S1 operates at the same frequency as the carrier signal. As previously stated, the modulation index M determines the form of the inverter output voltage V_{inv} and grid current I_g . Fig.'s 7-9 depict V_{inv} and I_g for various values of M . To inject current into the grid, set the dc-bus voltage to 400 V (greater than $\sqrt{2}V_g$, in this example, $V_g = 240$ V). Figure 9 shows that V_{inv} is less than $\sqrt{2}V_g$ since M is less than 0.5. The inverter should not operate at this condition because the current will be injected from the grid into the inverter, rather than the PV system injecting the current into the grid, as shown in Fig. 8. Over modulation condition, which happens when $M > 1.0$, is shown in Fig. 10. It has a flat top at the peak of the positive and negative cycles because both the reference signals exceed the maximum amplitude of the carrier signal. This will cause I_g to have a flat portion at the peak of the sine waveform, as shown in Fig. 11. To optimize the power transferred from PV arrays to the grid, it is recommended to operate at $0.5 < M < 1.0$. V_{inv} and I_g for optimal operating condition. As shown in fig.8,9. I_g is almost a pure sine wave, the THD can be reduced compared with that below of other values of M . The performance of the PI current control scheme has analyzed, a sudden step change is applied to the simulation process. This step change is similar to real-time environment condition (for example, the sun is emerging from the clouds). The Table 2 show the comparison of THD values.

CONCLUSION

This study describes the modeling and simulation of a five-level inverter driven by renewable energy sources. There are two sources of electricity: solar and wind. A boost converter for a solar photovoltaic system and a buck converter for a wind energy system maintain a steady output voltage. A five-level inverter converts the battery's dc voltage to ac power and connects it to the grid. The use of a five-level inverter decreases THD in output voltage and helps to eliminate the need for bulk filters on the output side. With an increase in the number of levels, the resulting output waveform becomes a staircase wave with more steps, approaching the required sinusoidal waveform. The proposed five-level inverter topology has less number of switches and input DC sources in comparison with conventional cascaded H-bridge configuration.

REFERENCES

1. J. Rodríguez, J. S. Lai and F. Z. Peng, —Multilevel inverters: A survey of topologies, controls and applications, IEEE Trans. Ind. Electron., vol. 49, no. 4, pp. 724–738, Aug. 2002.
2. M. Calais and V. G. Agelidis, —Multilevel converters for single-phase grid connected photovoltaic systems— an overview, in Proc. IEEE Int. Symp. Ind. Electron, 1998, vol. 1, pp. 224–229.
3. S. B. Kjaer, J. K. Pedersen, and F. Blaabjerg, —A review of single-phase grid connected inverters for photovoltaic modules, IEEE Trans. Ind. Appl., vol. 41, no. 5, pp. 1292–1306, Sep/Oct. 2000.
4. L. M. Tolbert, F. Z. Peng, “Multilevel Converters as a Utility Interface for Renewable Energy Systems,” IEEE Power Engineering Society Summer Meeting, Seattle, Washington, July 15-20, 2000, pp. 1271-1274.
5. S. A. Khajehoddin, A. Bakhshai, P. Jain, “The Application of the Cascaded Multilevel Converters in Grid Connected Photovoltaic Systems,” IEEE Canada Electrical Power Conference, 25-26 Oct. 2007, pp. 296-301.





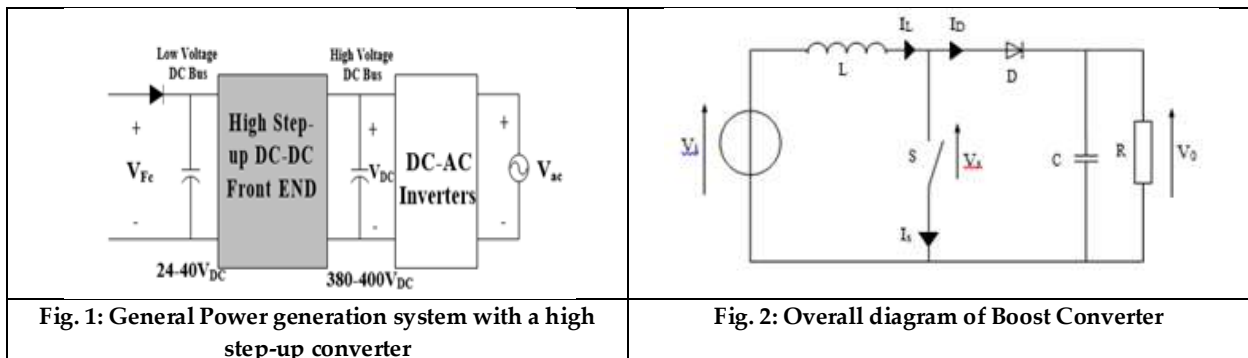
6. S. Alepuz, S. Busquets-Monge, J. Bordonau, J. Gago, D. Gonzalez and J. Balcells, "Interfacing renewable energy sources to the utility grid using a three-level inverter," IEEE Trans. Ind. Electron., vol. 53, no. 5, pp. 1504– 1511, Oct. 2006.
7. Jeyraj selvaraj and Nazrudin A.Rahim, "Multilevel inverter for grid connected PV system employing digital PI controller," IEEE Transactions on Industrial Electronics, vol.56, No.1 January 2009.
8. Shagar Banu M, Vinod S, Lakshmi.S, "Design of DC-DC converter for hybrid wind solar energy system", 2012 International conference on Computing, Electronics and Electrical Technologies, 2012.

Table 1: The Switching Sequence

S ₁	S ₂	S ₃	S ₄	S ₅	V _{inv}
0	1	0	0	1	V _{dc}
1	0	0	0	1	V _{dc} /2
0	1	0	1	0	0
0	0	1	0	1	
1	0	0	1	0	-V _{dc} /2
0	0	1	1	0	-V _{dc}

Table 2: The Comparison of THD Values

level	THD
5-level	48.56%
7-level	26.41%





<p>Fig. 3: Waveforms of current and voltage in a boost converter operating in continuous mode</p>	<p>Fig. 4: Waveforms of current and voltage in a boost converter operating in discontinuous mode</p>
<p>Fig. 5: Symmetrical Cascaded H-Bridge Inverter with five level</p>	<p>Fig. 6: The Architecture of Proposed System</p>
<p>Fig. 7: Output Voltage Waveform of the Proposed System</p>	<p>Fig. 8: Grid Currents of the Proposed System</p>





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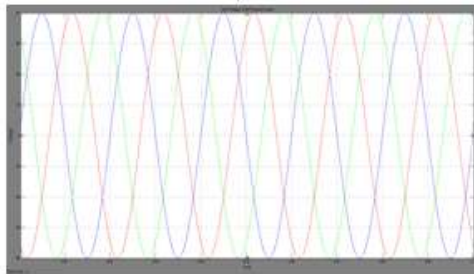


Fig. 9: Grid Voltages of the Proposed System

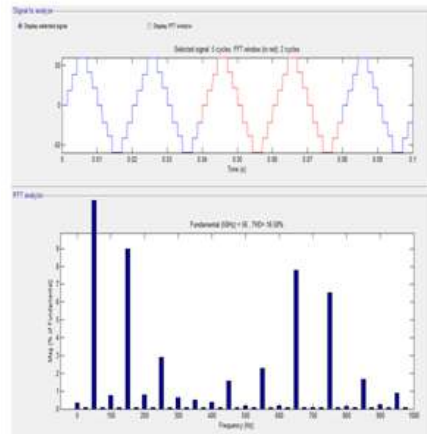


Fig. 10: THD for a Five Level Inverter

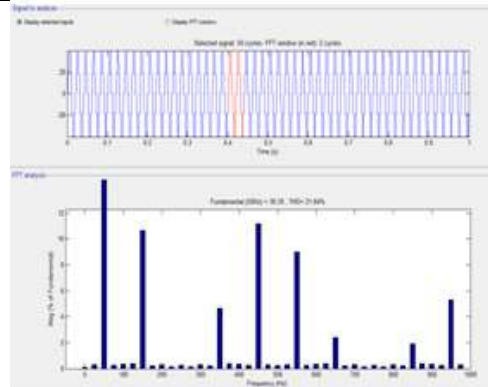


Fig. 11: THD for a Seven Level Inverter





Enhancing Transdermal Drug Delivery: the Pivotal Role of Ethosomal Nanoparticles in Overcoming Skin Barrier Challenges

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ABSTRACT

Transdermal drug delivery systems (TDDS) offer a promising alternative to oral and invasive administration routes by delivering medications directly through the skin's layers into the systemic circulation, thus avoiding first-pass metabolism and ensuring sustained release. Despite the potential, the skin's barrier, primarily the stratum corneum, presents significant challenges to effective drug delivery, necessitating innovative solutions. Ethosomal nanoparticles have emerged as a novel carrier system overcoming these barriers. These soft, malleable vesicles, composed of phospholipids, ethanol, and water, have shown superiority over traditional carriers like liposomes due to their enhanced skin permeation capabilities. Ethanol, a crucial component, disrupts the lipid organization of the stratum corneum, increasing its fluidity and permeability, thereby facilitating deeper penetration of drugs. Ethosomes can encapsulate a wide range of therapeutic agents, including lipophilic and hydrophilic drugs, peptides, and biological molecules, demonstrating their versatility across various therapeutic areas. The article highlights the application of ethosomal nanoparticles in formulating drugs like diclofenac, lidocaine, ketoconazole, testosterone, and estradiol for transdermal delivery, showing improved skin permeation, efficacy, and patient compliance. These advancements underscore the potential of ethosomal nanoparticles to revolutionize transdermal drug delivery, offering non-invasive, targeted, and controlled therapeutic strategies.





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Keywords: Transdermal drug delivery, Ethosomal nanoparticles, Skin permeation, Controlled release, Nanoparticle carriers.

INTRODUCTION

Overview of transdermal drug delivery systems (TDDS) and their importance

Transdermal Drug Delivery Systems (TDDS) represent a sophisticated approach to drug administration, designed to deliver medications through the skin's layers directly into the systemic circulation. This method offers a promising alternative to oral and invasive routes, circumventing the gastrointestinal tract and avoiding first-pass metabolism, thereby ensuring a more controlled and sustained release of therapeutic agents. TDDS is characterized by its non-invasiveness, improved patient compliance, and ability to maintain steady drug plasma concentrations over extended periods.[1] The significance of TDDS lies in its potential to revolutionize the pharmacokinetic profiles of drugs. By facilitating a direct entry into the systemic circulation, TDDS can potentially enhance the bioavailability of medications, an advantage particularly beneficial for drugs with poor oral bioavailability or those susceptible to significant hepatic metabolism. Additionally, transdermal delivery can reduce the risk of side effects associated with systemic drug distribution, targeting the action of drugs to specific sites as needed.[2] Technological advancements in TDDS have led to the development of various delivery systems, including patches, gels, and nanoparticles, each designed to overcome the stratum corneum's barrier properties—the outermost layer of the skin known for its formidable resistance to substance penetration. Among these innovations, ethosomal nanoparticles have nanoparticles are capable of encapsulating a wide range of therapeutic molecules, offering enhanced penetration through the lipid layers of the skin.[3] The importance of TDDS, and particularly the role of ethosomal nanoparticles, cannot be overstated. By providing a means to bypass the limitations of traditional administration routes, TDDS opens new avenues for the treatment of chronic conditions, pain management, and hormone therapy, among others. As research continues to advance in this field, the development of more efficient and patient-friendly transdermal delivery systems holds the promise of significantly impacting future therapeutic strategies.[4]

Skin's barrier properties and the challenges they pose to TDDS

The skin, the largest organ of the human body, serves as a critical barrier protecting the body from external aggressors while maintaining homeostasis. Its barrier function is primarily attributed to the stratum corneum, the outermost layer, which is composed of corneocytes (dead keratinocytes) embedded in a lipid-rich matrix. This unique structure provides the skin with its remarkable resilience and impermeability, posing significant challenges to transdermal drug delivery systems (TDDS).[5] The primary obstacle presented by the skin's barrier is its lipophilic nature, which favors the permeation of small, lipophilic molecules while hindering the passage of large, hydrophilic compounds. Additionally, the intercellular lipid matrix of the stratum corneum acts as a formidable barrier, limiting the diffusion of most substances. For TDDS, this means that only drugs with specific physicochemical properties namely, a balanced lipophilicity and small molecular size can efficiently penetrate the skin.[6] The rate of drug release and penetration through the skin. Achieving a controlled and sustained release, ensuring that the drug maintains its efficacy over time without causing irritation or sensitization, is critical. Furthermore, the skin's variability among individuals, due to factors like age, skin type, and the presence of skin conditions, can significantly affect the performance of TDDS, necessitating personalized approaches in some cases.[7] These challenges require innovative strategies to enhance skin permeability and facilitate the effective transport of therapeutic agents. Techniques such as the use of chemical enhancers, physical methods like microneedles, and the development of novel carriers like ethosomal nanoparticles are being explored to improve the efficacy of TDDS. These approaches aim to disrupt the stratum corneum's lipid matrix or create transient pathways, enabling the increased penetration of drugs without compromising the skin's barrier integrity.[8]





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Introduction to ethosomal nanoparticles and their relevance in enhancing transdermal drug delivery

Ethosomal nanoparticles are an innovative class of drug delivery carriers that have garnered significant attention for their ability to enhance transdermal drug delivery. Ethosomes are soft, malleable vesicles composed primarily of phospholipids, high concentrations of ethanol, and water. The unique composition of these nanoparticles enables them to effectively deliver a wide range of therapeutic agents through the skin's barrier, particularly the stratum corneum.[9] The mechanism by which ethosomal nanoparticles enhance transdermal delivery is multifaceted. Ethanol, a key component, plays a crucial role by providing ethosomes with a soft and flexible structure, allowing them to penetrate the skin more efficiently than traditional liposomes. Furthermore, ethanol disrupts the lipid organization of the stratum corneum, increasing its fluidity and permeability, which facilitates the deeper penetration of the encapsulated drug into the skin layers.[10] The phospholipid composition of ethosomal nanoparticles is biocompatible and mimics the lipid structure of the skin, which promotes the integration and interaction of these nanoparticles with the skin's lipid bilayers. This compatibility enhances the delivery of the drug into the deeper layers of the skin, improving its bioavailability and efficacy.[11] Ethosomal nanoparticles are versatile carriers capable of encapsulating a wide array of therapeutic agents, including lipophilic and hydrophilic drugs, peptides, and biological molecules. Their ability to enhance the transdermal delivery of these diverse compounds makes them a powerful tool in the field of transdermal drug delivery. The application of ethosomal nanoparticles can significantly improve the treatment of various conditions, offering a non-invasive and patient-friendly alternative to traditional drug delivery methods, thereby holding the promise to revolutionize the administration of therapeutics.[12]

Skin Barrier and Transdermal Drug Delivery

Detailed description of the skin's structure and its role as a barrier:[13]

The skin, serving as the body's outermost protective layer, is a complex organ composed of three primary layers: the epidermis, dermis, and hypodermis. Each layer plays a pivotal role in maintaining the skin's barrier function and overall integrity. The epidermis, the outermost layer, acts as a shield against environmental hazards such as pathogens, chemicals, and ultraviolet radiation. It is predominantly made up of keratinocytes, which undergo a process of differentiation to form the stratum corneum, the epidermis's outermost layer. The stratum corneum consists of dead keratinocytes (corneocytes) embedded in a lipid-rich matrix, which is crucial for its barrier function. This layer is responsible for the skin's water retention and protection against foreign substances. Beneath the epidermis lies the dermis, a thicker layer that provides structural support and elasticity to the skin. It is composed of collagen and elastin fibers, which confer tensile strength and flexibility, respectively. The dermis houses various appendages and structures, including hair follicles, sweat glands, and blood vessels, which play roles in thermoregulation, sensation, and nutrient supply. The deepest layer, the hypodermis or subcutaneous tissue, consists of adipose tissue and provides insulation, energy storage, and cushioning against mechanical impacts. The hypodermis also serves as an anchoring layer that connects the skin to underlying tissues and organs. The skin's barrier function is primarily attributed to the epidermis, particularly the stratum corneum, which prevents the loss of water and electrolytes while blocking the entry of harmful substances and microorganisms. This barrier is dynamically regulated, responding to environmental changes and injuries to maintain the skin's integrity and protect the body's internal environment.

Common challenges faced by transdermal drug delivery systems due to the skin's barrier properties:

Transdermal drug delivery systems (TDDS) face several challenges due to the inherent barrier properties of the skin, particularly the stratum corneum. The stratum corneum's primary function is to protect the body from external threats and prevent excessive water loss, but these protective mechanisms also impede the efficient delivery of therapeutic agents.[14] Firstly, the lipophilic nature of the stratum corneum favors the permeation of small, lipid-soluble molecules while excluding large, hydrophilic molecules. This selective permeability restricts the range of drugs that can be effectively delivered transdermally, often necessitating the use of enhancers or carriers to facilitate transport. Secondly, the skin's barrier function varies significantly across different body sites and among individuals, influenced by factors such as age, skin type, and the presence of skin diseases. These variations can lead to inconsistent drug absorption rates, complicating the dosing and efficacy of transdermal therapies.[15] The presence of metabolic enzymes within the skin also poses a challenge, as they can degrade drugs before they reach systemic



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circulation, reducing the drug's bioavailability and efficacy. Additionally, the potential for skin irritation or sensitization due to the drug or accompanying formulation ingredients can limit the use of TDDS, impacting patient compliance.[16] These challenges requires innovative approaches, such as the use of penetration enhancers, which temporarily disrupt the skin's barrier, or the development of novel carriers like nanoparticles, which can enhance drug solubility and promote penetration. Techniques such as microneedles, iontophoresis, and sonophoresis also offer methods to bypass or reduce the barrier function of the skin, facilitating the delivery of a wider range of drugs transdermally.[17]

Overview of traditional methods used to overcome these challenges and their limitations

Traditional methods employed to overcome the skin's barrier challenges in transdermal drug delivery primarily focus on enhancing the permeability of the stratum corneum to facilitate drug penetration. These methods can be broadly categorized into chemical and physical strategies. Chemical enhancers are compounds that transiently disrupt the lipid matrix of the stratum corneum, increasing its permeability. These include substances such as fatty acids, alcohols, surfactants, and terpenes. While effective, the use of chemical enhancers can be limited by their potential to cause skin irritation or toxicity, especially with long-term use. Additionally, the enhancement effect can vary significantly based on the enhancer's concentration and the specific drug formulation, requiring careful optimization to achieve the desired permeation without compromising skin integrity.[18] Physical methods include techniques such as microneedle arrays, which create micro-scale punctures in the skin to allow drug passage, and iontophoresis, which uses an electrical current to drive charged molecules into the skin. Sonophoresis, or ultrasound, is another method that increases skin permeability by using acoustic waves to temporarily disrupt the stratum corneum. While these physical methods can be highly effective, they may require specialized equipment and can increase the complexity and cost of treatment. Moreover, there is a risk of causing skin irritation or damage, particularly with improper use. Both chemical and physical methods have made significant contributions to enhancing transdermal drug delivery. However, their limitations underscore the need for innovative approaches that can safely and efficiently facilitate drug transport through the skin's barrier without causing adverse effects, paving the way for the development of advanced carriers like ethosomal nanoparticles.[19]

Ethosomal Nanoparticles: An Overview**Definition and characteristics of ethosomal nanoparticles**

Ethosomal nanoparticles are cutting-edge carriers in the field of transdermal drug delivery, designed to enhance the permeation of drugs through the skin. These nanoparticles are characterized by their unique composition, which typically includes phospholipids, high concentrations of ethanol, and water. The inclusion of ethanol, particularly at high concentrations, distinguishes ethosomes from traditional liposomes, endowing them with distinct characteristics that enhance their skin permeation capabilities.[20] The structural foundation of ethosomal nanoparticles is phospholipids, which form a bilayer vesicle encapsulating an aqueous core. This configuration allows for the incorporation of a wide range of therapeutic agents, irrespective of their solubility. Ethanol serves multiple roles within this system: it fluidizes the lipid bilayer, increases the vesicles' flexibility, and disrupts the skin's lipid matrix, thereby facilitating enhanced penetration of the encapsulated drug. Ethanol aids in the solubilization of hydrophilic drugs within the ethosomal system, increasing the overall encapsulation efficiency.[21] Ethosomal nanoparticles typically exhibit sizes ranging from tens to hundreds of nanometers, allowing them to deeply penetrate the skin layers. Their size and flexibility enable them to traverse the stratum corneum more effectively than rigid liposomal structures. Once applied to the skin, ethosomes can merge with cellular lipids, further facilitating the delivery of their cargo into deeper skin layers or even into systemic circulation.[22] The ability of ethosomal nanoparticles to carry both lipophilic and hydrophilic drugs, combined with their enhanced skin permeation properties, makes them an advantageous platform for transdermal drug delivery. These characteristics allow for improved bioavailability, controlled release, and potentially reduced systemic side effects, marking ethosomes as a significant advancement in the field of non-invasive drug delivery systems.[23]





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Composition and mechanism of action of ethosomal nanoparticles in transdermal delivery

Ethosomal nanoparticles are composed of phospholipids, ethanol, and water, forming a vesicular carrier system designed to enhance transdermal drug delivery. Phospholipids, the primary structural component, form a bilayer similar to biological membranes, encapsulating the drug in an aqueous core or intercalating it within the lipid bilayer, depending on the drug's lipophilicity. Ethanol, a key component in ethosomes, typically incorporated at high concentrations, plays a multifaceted role in enhancing the delivery of drugs through the skin.[24] The mechanism of action of ethosomal nanoparticles in transdermal delivery is attributed to the combined effects of their components. Ethanol disrupts the skin's lipid matrix, increasing its fluidity and permeability. This disruption facilitates the deeper penetration of the ethosomal carriers into the skin. Moreover, ethanol enhances the fluidity of the ethosomal membrane itself, making the vesicles more malleable and capable of navigating through the tight intercellular spaces of the stratum corneum.[25] The phospholipid composition of ethosomes not only allows for the encapsulation of a diverse range of drugs but also contributes to the biocompatibility and integration of these carriers with the skin's lipid structures. This compatibility is crucial for the effective transdermal delivery and sustained release of therapeutic agents. Upon application to the skin, ethosomes interact with the stratum corneum's lipid components, facilitating the release and penetration of the encapsulated drug. The drug can then reach deeper skin layers or enter systemic circulation, depending on the intended therapeutic outcome. This delivery mechanism, combined with the vesicles' ability to encapsulate various drugs and protect them from enzymatic degradation, underscores the utility of ethosomal nanoparticles in overcoming the challenges of transdermal drug delivery.[26]

Comparison of ethosomal nanoparticles with conventional carriers

Ethosomal nanoparticles and conventional liposomes are both vesicular systems used in drug delivery, but they possess distinct characteristics that influence their performance, particularly in transdermal delivery. Liposomes are spherical vesicles composed of phospholipid bilayers encapsulating an aqueous core. They have been extensively used to enhance the solubility, stability, and bioavailability of various drugs. However, in the context of transdermal delivery, liposomes face limitations due to their relatively rigid structure, which can hinder their ability to penetrate the tightly packed stratum corneum effectively.[27] Ethosomal nanoparticles are similar in structure to liposomes but include a high concentration of ethanol in their composition. This key difference endows ethosomes with several advantages over traditional liposomes. Ethanol disrupts the lipid bilayers of the stratum corneum, enhancing skin permeability and facilitating the deeper penetration of the ethosomes. Ethanol contributes to the fluidity and flexibility of the ethosomal membrane, allowing these nanoparticles to more effectively navigate through the skin's barrier layers.[28] The enhanced permeation properties of ethosomes translate to improved drug delivery efficiency through the skin compared to conventional liposomes. Ethosomes can deliver a wider range of molecules, including hydrophilic, lipophilic, and amphiphilic compounds, across the skin barrier. Furthermore, the interaction of ethanol with skin lipids can lead to a depot effect, where the drug is released gradually, ensuring a sustained therapeutic effect. While both ethosomal nanoparticles and liposomes offer advantages such as biocompatibility and the ability to encapsulate diverse drugs, ethosomes stand out in the context of transdermal drug delivery due to their enhanced skin penetration capabilities, offering a promising approach for non-invasive therapeutic applications.[29]

Role of Ethosomal Nanoparticles in Overcoming Skin Barrier Challenges

Penetration of ethosomal nanoparticles to skin barrier:

Ethosomal nanoparticles penetrate the skin barrier through a mechanism that leverages their unique composition, particularly the high ethanol content, which differentiates them from conventional vesicular carriers. This detailed penetration process involves several key interactions and structural advantages that facilitate the transdermal delivery of encapsulated drugs.[30] Firstly, the high ethanol concentration in ethosomes plays a pivotal role in disrupting the lipid organization of the stratum corneum, the outermost layer of the skin. Ethanol induces fluidization of the lipid bilayers, temporarily reducing their density and cohesiveness, which increases the skin's permeability. This disruption allows ethosomal nanoparticles to traverse the stratum corneum more effectively than traditional liposomes. Secondly, the ethanol in ethosomes enhances the flexibility and deformability of the vesicles themselves. This malleability enables ethosomes to conform to the micro-contours of the skin surface and pass through the intercellular spaces of the stratum corneum, facilitating deeper penetration into the skin layers. The



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flexible nature of ethosomes contrasts with the relatively rigid structure of conventional liposomes, providing a substantial advantage in transdermal delivery.[31] The interaction between the phospholipid components of ethosomes and the skin's lipids may promote the fusion of ethosomes with skin cells, further aiding in the delivery of the encapsulated drug. Once the ethosomes penetrate the stratum corneum, they can release their payload into the deeper skin layers, where the drug can exert its therapeutic effect or enter the systemic circulation.[32] The penetration of ethosomal nanoparticles through the skin barrier is a multifaceted process that capitalizes on the ethanol-induced disruption of the skin's lipid matrix, the enhanced flexibility of the ethosomes, and their interaction with skin cell lipids. This combination of factors makes ethosomes a highly effective vehicle for transdermal drug delivery.[33]

Studies and evidence showcasing the effectiveness of ethosomal nanoparticles in enhancing drug permeation through the skin

Numerous studies have been conducted to evaluate the effectiveness of ethosomal nanoparticles in enhancing drug permeation through the skin, demonstrating their potential as a superior transdermal drug delivery system. These studies often compare the transdermal delivery efficacy of ethosomes to conventional carriers like liposomes and hydrogels, using various pharmacological agents.[34] A study by Touitou et al., the pioneers in ethosomal research, demonstrated the enhanced delivery of minoxidil through human skin using ethosomes compared to traditional formulations. The ethosomal formulation showed a significant increase in minoxidil skin permeation and retention, which could be beneficial for conditions like alopecia.[35] Another notable study focused on the transdermal delivery of insulin using ethosomes. The research indicated that insulin-loaded ethosomes significantly increased the permeation of insulin through rat skin compared to conventional liposomes and aqueous solutions. This result suggests that ethosomes could be a promising non-invasive alternative for insulin delivery, improving patient compliance and potentially reducing the risk of systemic side effects associated with oral or injectable routes.[36] The use of ethosomes for the transdermal delivery of anti-inflammatory drugs, such as diclofenac, has shown promising results. Ethosomal formulations of diclofenac demonstrated enhanced skin permeation and improved anti-inflammatory effects in animal models compared to traditional gels and creams. These studies are corroborated by various *in vitro* and *in vivo* experiments, employing techniques like Franz diffusion cells for *in vitro* permeation studies and histological examinations to observe the distribution of drugs in skin layers. The collective evidence from these studies highlights the superior capability of ethosomal nanoparticles to enhance the permeation of a wide range of drugs through the skin, offering a potent alternative to traditional transdermal delivery systems.[37]

Comparison of ethosomal nanoparticles' efficiency with other transdermal enhancement strategies

Ethosomal nanoparticles have emerged as a prominent strategy in transdermal drug delivery, exhibiting distinct advantages over other enhancement techniques. When compared to traditional methods like chemical enhancers, physical methods, and other nanocarrier systems, ethosomes demonstrate a unique combination of efficacy, safety, and versatility.[38] Chemical enhancers, such as dimethyl sulfoxide (DMSO) or azone, temporarily disrupt the skin barrier to facilitate drug penetration. However, their application can often lead to skin irritation or systemic toxicity with prolonged use. Ethosomes employ ethanol—a generally less irritating solvent—that transiently disrupts the skin barrier while also stabilizing the vesicular structure, thereby facilitating efficient drug transport with minimal irritation.[39] Physical methods like microneedles, iontophoresis, or sonophoresis also enhance transdermal drug delivery. Microneedles create microchannels in the skin to bypass the stratum corneum, while iontophoresis and sonophoresis use electric current and ultrasound, respectively, to enhance skin permeability. While effective, these methods require additional equipment and can cause discomfort or skin irritation. Ethosomes, on the other hand, offer a non-invasive and patient-friendly approach, eliminating the need for external devices or potentially painful administration.[40] When compared to other nanocarrier systems, such as liposomes or solid lipid nanoparticles, ethosomes exhibit superior skin permeation due to their ethanol content, which enhances their fluidity and interaction with skin lipids. While liposomes and solid lipid nanoparticles improve drug stability and release, their penetration efficiency is generally lower than that of ethosomes, which can merge with cellular lipids and enhance drug transport across the skin barrier. Ethosomal nanoparticles represent an advanced transdermal enhancement





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strategy, combining the biocompatibility and versatility of nanocarriers with the permeation-enhancing effects of ethanol, resulting in improved drug delivery efficiency compared to conventional methods and carriers.[41]

Applications of Ethosomal Nanoparticles in Transdermal Drug Delivery

Examples of drugs that have been successfully formulated with ethosomal nanoparticles for transdermal delivery

Ethosomal nanoparticles have been successfully employed to formulate a variety of drugs for enhanced transdermal delivery across diverse therapeutic areas. These include anti-inflammatory agents, anesthetics, antifungal medications, and hormones, showcasing the versatility of ethosomes in transdermal drug delivery.[42] One notable example is the formulation of diclofenac, a non-steroidal anti-inflammatory drug (NSAID), into ethosomal carriers. Studies have demonstrated that diclofenac-loaded ethosomes significantly enhance the drug's skin permeation and retention compared to conventional formulations. This enhanced delivery could improve the treatment of conditions like arthritis, offering localized relief with reduced systemic side effects.[43] Another example is the transdermal delivery of lidocaine, a local anesthetic. Ethosomal formulations of lidocaine have shown superior skin permeation, providing a rapid onset of anesthesia, which can be particularly beneficial for pain management and minor surgical procedures.[44] Antifungal drugs, such as ketoconazole, have also been formulated using ethosomes. The ethosomal delivery of ketoconazole has exhibited improved penetration through the skin, which could enhance the treatment of fungal infections by achieving higher drug concentrations at the site of infection.[45] Ethosomes have been explored for the transdermal delivery of hormones, such as testosterone and estradiol. These formulations can potentially offer a convenient and consistent method of hormone replacement therapy, avoiding the fluctuations in hormone levels associated with oral or injectable routes.[46] These examples highlight the potential of ethosomal nanoparticles to improve the efficacy, safety, and patient acceptability of transdermal drug delivery across a range of pharmaceutical applications. By enhancing the skin permeation of drugs, ethosomes offer a promising platform for non-invasive, targeted, and controlled drug delivery.

Therapeutic areas where ethosomal nanoparticles could provide significant benefits:(e.g., pain management, hormonal therapy, etc.)

Ethosomal nanoparticles, with their unique ability to enhance transdermal drug delivery, hold significant potential across various therapeutic areas. By facilitating the controlled release and improved skin penetration of drugs, ethosomes can revolutionize treatment approaches in pain management, hormonal therapy, dermatology, and systemic diseases.[47] In pain management, ethosomes can deliver analgesic and anti-inflammatory drugs directly to the affected area, providing localized relief while minimizing systemic side effects. For instance, the ethosomal formulation of non-steroidal anti-inflammatory drugs (NSAIDs) or local anesthetics can offer an effective and patient-friendly alternative to oral administration or injections, potentially improving compliance and patient comfort.[48] Hormonal therapy is another area where ethosomes could provide substantial benefits. The transdermal delivery of hormones like estradiol or testosterone using ethosomal nanoparticles can ensure steady blood levels, avoiding the peaks and troughs associated with oral or injectable routes. This could enhance the efficacy and safety of hormone replacement therapies, providing a more consistent therapeutic effect and reducing the risk of side effects.[49] In dermatology, ethosomes can enhance the delivery of antifungal, antibacterial, and anti-inflammatory agents directly to the skin layers, improving the treatment of conditions like psoriasis, eczema, and fungal infections. The improved drug penetration and retention at the site of action can enhance therapeutic outcomes and reduce the dosage and frequency of drug application.[50] Furthermore, ethosomal nanoparticles could be beneficial in the systemic delivery of drugs for chronic conditions such as diabetes or cardiovascular diseases. By enabling transdermal delivery, ethosomes provide an alternative route of administration that could enhance patient adherence, especially for patients who face difficulties with oral medication or require long-term drug therapy. The application of ethosomal nanoparticles in these therapeutic areas can lead to more effective, safer, and patient-centered treatment modalities, showcasing their potential to significantly impact healthcare and patient outcomes.[51]





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Future potential applications and advancements in the field

The future potential applications and advancements in the field of ethosomal nanoparticles are vast and hold promise for revolutionizing transdermal drug delivery and beyond. Continued research and innovation are expected to expand the therapeutic scope, enhance efficiency, and improve patient outcomes across various medical disciplines.[52] One potential future application is in the realm of personalized medicine. By tailoring ethosomal formulations based on individual skin properties and drug response profiles, it may be possible to optimize therapy for individual patients, enhancing efficacy and minimizing adverse effects. This approach could be particularly beneficial in managing chronic conditions, where long-term treatment necessitates personalized strategies to ensure optimal outcomes.[53] In the field of vaccine delivery, ethosomal nanoparticles could offer a needle-free, painless, and user-friendly alternative to traditional injection-based immunizations. This could significantly improve vaccine accessibility and compliance, particularly in pediatric populations or regions with limited healthcare infrastructure.[54] Advancements in nanotechnology could further enhance the capabilities of ethosomal systems. Incorporating smart release systems, responsive to environmental or biological stimuli (such as pH, temperature, or enzymatic activity), could allow for controlled, site-specific drug release, maximizing therapeutic effects while minimizing systemic exposure.[55] Furthermore, the integration of ethosomal systems with wearable technology and biosensors represents a cutting-edge frontier. Such integration could enable real-time monitoring of drug delivery and physiological responses, facilitating dynamic dosing adjustments and providing valuable insights into treatment effectiveness and patient adherence. The future of ethosomal nanoparticles is poised for significant advancements, with potential applications extending into personalized medicine, vaccine delivery, smart release systems, and integrated wearable technologies. These advancements promise to enhance the precision, efficacy, and patient-friendliness of transdermal drug delivery, offering exciting prospects for the future of healthcare and therapeutic interventions.[56]

ADVANTAGES AND LIMITATIONS

Advantages of using ethosomal nanoparticles in TDDS, including enhanced permeation, controlled release, and patient compliance

Ethosomal nanoparticles offer several advantages in transdermal drug delivery systems (TDDS) that address the limitations of conventional transdermal and systemic delivery methods. These advantages include enhanced skin permeation, controlled drug release, and improved patient compliance, contributing to the overall effectiveness and appeal of ethosomal formulations in clinical applications.[57] Enhanced skin permeation is one of the primary benefits of ethosomal nanoparticles. The high ethanol content in ethosomes disrupts the lipid organization of the stratum corneum, increasing its fluidity and permeability. This mechanism facilitates the deeper penetration of drugs encapsulated in ethosomes compared to traditional formulations, ensuring efficient drug delivery through the skin barrier. Moreover, the flexibility and size of ethosomal nanoparticles allow them to traverse the skin's microstructure more effectively, enhancing the bioavailability of the therapeutic agent.[58] Controlled release is another significant advantage of ethosomes. The encapsulation of drugs within the vesicular structure of ethosomes allows for a sustained and controlled release, maintaining therapeutic drug levels over an extended period. This controlled release can minimize the fluctuations in drug concentration associated with conventional dosing, reducing the risk of side effects and improving therapeutic outcomes.[59] Improved patient compliance is a critical advantage of using ethosomal nanoparticles in TDDS. The non-invasive nature of transdermal delivery eliminates the discomfort and anxiety associated with injections and the inconvenience of frequent dosing schedules. Ethosomal formulations can be designed as user-friendly topical applications, such as gels or patches, which are easy to apply and can be incorporated into daily routines. This ease of use, coupled with reduced side effects and improved efficacy, can significantly enhance patient adherence to treatment regimens, contributing to better health outcomes.[60] The advantages of ethosomal nanoparticles in TDDS, including enhanced permeation, controlled release, and improved patient compliance, highlight their potential to transform transdermal drug delivery, offering a more effective, patient-friendly, and innovative approach to therapy.



**Mashaerabdelazim Ibrahim Bakhit et al.,****Addressing the limitations and challenges associated with the development and use of ethosomal nanoparticles**

Despite the promising advantages of ethosomal nanoparticles in transdermal drug delivery, there are several limitations and challenges associated with their development and use that need to be addressed to fully realize their potential. One of the primary challenges is the stability of ethosomal formulations. The high ethanol content, while beneficial for enhancing skin permeation, can lead to volatility and evaporation issues, potentially affecting the stability and consistency of the formulation. Additionally, the interaction between ethanol and the phospholipid bilayer can influence the physical stability of the vesicles, which may undergo aggregation or fusion during storage, affecting their size, distribution, and drug release properties.[61] Another challenge is the potential for skin irritation or toxicity. Although ethanol is generally regarded as safe, high concentrations or prolonged exposure can cause skin dryness, irritation, or even dermatitis. Ensuring the biocompatibility and safety of ethosomal formulations is crucial, necessitating thorough *in vitro* and *in vivo* toxicity testing to establish safe concentration thresholds for ethanol and other components.[62] The scalability of ethosomal production is also a concern. While laboratory-scale synthesis of ethosomes can be achieved, scaling up the production process to industrial levels while maintaining the quality and uniformity of the nanoparticles can be challenging. This includes ensuring consistent vesicle size, drug encapsulation efficiency, and stability across large batches, which is essential for clinical and commercial applications.[63] Regulatory challenges must be considered. As with any novel drug delivery system, ethosomes must undergo rigorous regulatory scrutiny to demonstrate their safety, efficacy, and quality. Obtaining regulatory approval can be a complex and time-consuming process, requiring comprehensive documentation of preclinical and clinical data.[64] Limitations and challenges is crucial for the successful development and clinical translation of ethosomal nanoparticles, requiring ongoing research, innovation, and collaboration between academia, industry, and regulatory bodies.

Future Perspectives**Potential areas for future research in the development and optimization of ethosomal nanoparticles for transdermal delivery:[65]**

Future research in the development and optimization of ethosomal nanoparticles for transdermal delivery is pivotal to unlocking their full therapeutic potential. Several areas hold promise for advancing the science and application of ethosomes:

1. **Formulation Stability:** Enhancing the physical and chemical stability of ethosomal formulations is crucial. Future studies could focus on optimizing the composition and processing conditions to improve the long-term stability of ethosomes, including strategies to minimize ethanol evaporation and phospholipid degradation.
2. **Skin Irritation and Safety:** Research aimed at understanding and mitigating the potential skin irritation or toxicity associated with ethosomes, particularly due to their ethanol content, is essential. Developing strategies to reduce ethanol concentration while maintaining the vesicles' permeation-enhancing properties could be a key focus area.
3. **Drug Release Kinetics:** Further studies are needed to elucidate the drug release mechanisms from ethosomes and how they interact with skin tissues. This knowledge can aid in designing ethosomes with tailored release profiles for different drugs and therapeutic indications.
4. **Penetration Mechanisms:** Although the skin penetration enhancement by ethosomes is recognized, detailed mechanistic studies at the molecular level could provide deeper insights into the interactions between ethosomes and skin components, facilitating the design of more effective formulations.
5. **Targeted Delivery:** Research could explore the targeting capabilities of ethosomes, potentially by functionalizing their surface with targeting ligands or antibodies to direct the encapsulated drugs to specific cell types or tissues.
6. **Combination Therapies:** Investigating the co-delivery of multiple drugs or therapeutic agents using ethosomes could offer novel approaches for synergistic or multimodal treatments, particularly for complex skin conditions or systemic effects.





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7. **Regulatory and Manufacturing Aspects:** Addressing the scalability and regulatory challenges associated with ethosomes is necessary for their transition from research to clinical and commercial use. Developing standardized protocols for production, characterization, and quality control can facilitate this process.

The future role of ethosomal nanoparticles in personalized medicine and wearable technology

Ethosomal nanoparticles hold significant promise in the realms of personalized medicine and wearable technology, offering innovative avenues to tailor and monitor therapeutic interventions more closely to individual patient needs. In personalized medicine, ethosomal nanoparticles can be optimized to accommodate individual variations in skin properties, drug metabolism, and disease states, allowing for more precise and effective treatments. Personalization could be achieved by adjusting the composition and dosage of ethosomal formulations based on genetic, biomarker, or phenotypic data. This approach would not only enhance the efficacy of transdermal therapies but also minimize the risk of adverse effects, aligning with the personalized medicine ethos of delivering the right treatment to the right patient at the right time.[66] The integration of ethosomal nanoparticles with wearable technology represents a frontier with immense potential. Wearable devices equipped with sensors could monitor various physiological parameters, such as skin temperature, hydration, and pH, providing real-time data that could inform the controlled release of drugs from ethosomal formulations. This could enable dynamic dosing strategies where drug release is adjusted based on real-time physiological feedback, optimizing therapeutic outcomes.[67] Moreover, wearable devices could be designed to apply ethosomal formulations at predetermined intervals or in response to specific triggers, enhancing treatment compliance and convenience. They could also facilitate the continuous monitoring of treatment efficacy and skin health, providing valuable data for healthcare providers to adjust treatment plans as needed.[68] The future integration of ethosomal nanoparticles with personalized medicine and wearable technology holds the potential to revolutionize transdermal drug delivery, offering more tailored, responsive, and patient-centric therapeutic solutions. This convergence of nanotechnology, personalized medicine, and digital health technology could significantly advance patient care and treatment outcomes in various medical fields.[69]

CONCLUSIONS

Summary of the key points discussed in the review

This review has explored the multifaceted role of ethosomal nanoparticles in enhancing transdermal drug delivery, highlighting their composition, mechanism of action, and advantages over conventional delivery systems. Ethosomal nanoparticles, characterized by their unique composition of phospholipids, high ethanol content, and water, offer a versatile platform for improving the transdermal permeation of various therapeutic agents. The key mechanism underlying the efficacy of ethosomes is their ability to disrupt the lipid matrix of the stratum corneum, facilitated by ethanol, which enhances skin permeability and allows for deeper penetration of encapsulated drugs. This feature, coupled with the flexibility and size of ethosomes, enables efficient drug transport across the skin barrier, addressing a critical challenge faced by traditional transdermal delivery systems. Ethosomes have demonstrated superior performance in delivering a range of drugs, including anti-inflammatory agents, anesthetics, antifungal medications, and hormones, across the skin barrier. Their ability to provide controlled and sustained release of drugs enhances therapeutic outcomes and patient compliance, reducing the need for frequent dosing and minimizing systemic side effects. Despite their advantages, the development and application of ethosomal nanoparticles face challenges related to formulation stability, skin irritation potential, scalability, and regulatory approval. Addressing these challenges through future research is crucial for the broader adoption and clinical translation of ethosomes. Ethosomes have the potential to play a pivotal role in personalized medicine and wearable technology, offering tailored and responsive drug delivery solutions that align with individual patient needs and physiological feedback. As research and technology in this field advance, ethosomal nanoparticles are poised to significantly impact the landscape of transdermal drug delivery and patient care.





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Impact of ethosomal nanoparticles in revolutionizing transdermal drug

Ethosomal nanoparticles represent a significant advancement in the field of transdermal drug delivery, offering a novel solution to overcome the intrinsic limitations of the skin barrier. Their unique composition, characterized by the inclusion of high ethanol concentrations, enables these nanocarriers to enhance the permeation and bioavailability of a wide range of therapeutic agents through the skin. The impact of ethosomal nanoparticles on transdermal drug delivery is multifaceted. They offer improved drug penetration, controlled release profiles, and the potential for targeted delivery, which collectively contribute to enhanced therapeutic efficacy and patient compliance. By providing a non-invasive route of administration, ethosomal nanoparticles reduce the discomfort and risks associated with injections and invasive procedures, promoting better patient adherence to treatment regimens. The versatility of ethosomal formulations allows for the encapsulation of diverse drug molecules, expanding the possibilities for transdermal therapeutic applications beyond what conventional carriers can offer. This versatility, combined with the potential for personalized medicine and integration with wearable technologies, positions ethosomal nanoparticles at the forefront of innovations in drug delivery systems. Ongoing research and development efforts are essential to address the existing challenges related to formulation stability, safety, and scalability. As these challenges are overcome and as more clinical evidence emerges, ethosomal nanoparticles are expected to transition from research laboratories to clinical practice, potentially revolutionizing the way drugs are delivered transdermally. Ethosomal nanoparticles hold the promise to significantly advance the field of transdermal drug delivery, offering more effective, patient-friendly, and sophisticated therapeutic solutions that could reshape treatment paradigms across various medical disciplines.

REFERENCES

1. Alkilani AZ, Nasereddin J, Hamed R, Nimrawi S, Hussein G, Abo-Zour H, Donnelly RF. Beneath the Skin: A Review of Current Trends and Future Prospects of Transdermal Drug Delivery Systems. *Pharmaceutics*. 2022 May 28;14(6):1152.
2. Laffleur F, Keckeis V. Advances in drug delivery systems: Work in progress still needed?. *International journal of pharmaceutics*. 2020 Nov 30;590:119912.
3. Zhou X, Hao Y, Yuan L, Pradhan S, Shrestha K, Pradhan O, Liu H, Li W. Nano-formulations for transdermal drug delivery: A review. *Chinese Chemical Letters*. 2018 Dec 1;29(12):1713-24.
4. Das Kurmi B, Tekchandani P, Paliwal R, Rai Paliwal S. Transdermal drug delivery: opportunities and challenges for controlled delivery of therapeutic agents using nanocarriers. *Current drug metabolism*. 2017 May 1;18(5):481-95.
5. Akombaetwa N, Ilangala AB, Thom L, Memvanga PB, Witika BA, Buya AB. Current Advances in Lipid Nanosystems Intended for Topical and Transdermal Drug Delivery Applications. *Pharmaceutics*. 2023 Feb 15;15(2):656.
6. Yu YQ, Yang X, Wu XF, Fan YB. Enhancing permeation of drug molecules across the skin via delivery in nanocarriers: novel strategies for effective transdermal applications. *Frontiers in bioengineering and biotechnology*. 2021 Mar 29;9:646554.
7. Lee H, Song C, Baik S, Kim D, Hyeon T, Kim DH. Device-assisted transdermal drug delivery. *Advanced drug delivery reviews*. 2018 Mar 1;127:35-45.
8. Yuan L, Pan M, Shi K, Hu D, Li Y, Chen Y, Qian Z. Nanocarriers for promoting skin delivery of therapeutic agents. *Applied Materials Today*. 2022 Jun 1;27:101438.
9. Pandey V, Golhani D, Shukla R. Ethosomes: versatile vesicular carriers for efficient transdermal delivery of therapeutic agents. *Drug delivery*. 2015 Nov 17;22(8):988-1002.
10. Jain S, Patel N, Shah MK, Khatri P, Vora N. Recent advances in lipid-based vesicles and particulate carriers for topical and transdermal application. *Journal of pharmaceutical sciences*. 2017 Feb 1;106(2):423-45.
11. Singh S, Awasthi R. Breakthroughs and bottlenecks of psoriasis therapy: Emerging trends and advances in lipid based nano-drug delivery platforms for dermal and transdermal drug delivery. *Journal of Drug Delivery Science and Technology*. 2023 May 12:104548.



**Mashaerabdelazim Ibrahim Bakhit et al.,**

12. Abd El-Alim SH, Kassem AA, Basha M, Salama A. Comparative study of liposomes, ethosomes and transfersomes as carriers for enhancing the transdermal delivery of diflunisal: in vitro and in vivo evaluation. *International journal of pharmaceutics*. 2019 May 30;563:293-303.
13. Benson HA. Skin structure, function, and permeation. *Topical and transdermal drug delivery: Principles and practice*. 2012:1-22.
14. Carter P, Narasimhan B, Wang Q. Biocompatible nanoparticles and vesicular systems in transdermal drug delivery for various skin diseases. *International journal of pharmaceutics*. 2019 Jan 30;555:49-62.
15. Yu YQ, Yang X, Wu XF, Fan YB. Enhancing permeation of drug molecules across the skin via delivery in nanocarriers: novel strategies for effective transdermal applications. *Frontiers in bioengineering and biotechnology*. 2021 Mar 29;9:646554.
16. Jhawar VC, Saini V, Kamboj S, Maggon N. Transdermal drug delivery systems: approaches and advancements in drug absorption through skin. *Int J Pharm Sci Rev Res*. 2013 May;20(1):47-56.
17. Phatale V, Vaiphei KK, Jha S, Patil D, Agrawal M, Alexander A. Overcoming skin barriers through advanced transdermal drug delivery approaches. *Journal of controlled release*. 2022 Nov 1;351:361-80.
18. Songkro S. An overview of skin penetration enhancers: penetration enhancing activity, skin irritation potential and mechanism of action. *Songklanakarin journal of science & technology*. 2009 May 1;31(3).
19. Yu YQ, Yang X, Wu XF, Fan YB. Enhancing permeation of drug molecules across the skin via delivery in nanocarriers: novel strategies for effective transdermal applications. *Frontiers in bioengineering and biotechnology*. 2021 Mar 29;9:646554.
20. Paiva-Santos AC, Silva AL, Guerra C, Peixoto D, Pereira-Silva M, Zeinali M, Mascarenhas-Melo F, Castro R, Veiga F. Ethosomes as nanocarriers for the development of skin delivery formulations. *Pharmaceutical research*. 2021 Jun;38(6):947-70.
21. Akombaetwa N, Ilangala AB, Thom L, Memvanga PB, Witika BA, Buya AB. Current Advances in Lipid Nanosystems Intended for Topical and Transdermal Drug Delivery Applications. *Pharmaceutics*. 2023 Feb 15;15(2):656.
22. Santos AC, Rodrigues D, Sequeira JA, Pereira I, Simoes A, Costa D, Peixoto D, Costa G, Veiga F. Nanotechnological breakthroughs in the development of topical phytocompounds-based formulations. *International Journal of Pharmaceutics*. 2019 Dec 15;572:118787.
23. Akhtar N, Akhtar N, Mena F, Alharbi W, Alaryani FS, Alqahtani AM, Ahmad F. Fabrication of ethosomes containing tocopherol acetate to enhance transdermal permeation: In vitro and ex vivo characterizations. *Gels*. 2022 May 30;8(6):335.
24. Mbah CC, Builders PF, Attama AA. Nanovesicular carriers as alternative drug delivery systems: ethosomes in focus. *Expert opinion on drug delivery*. 2014 Jan 1;11(1):45-59.
25. Kahraman E, Güngör S, Özsoy Y. Potential enhancement and targeting strategies of polymeric and lipid-based nanocarriers in dermal drug delivery. *Therapeutic delivery*. 2017 Nov;8(11):967-85.
26. Li Y, Xu F, Li X, Chen SY, Huang LY, Bian YY, Wang J, Shu YT, Yan GJ, Dong J, Yin SP. Development of curcumin-loaded composite phospholipid ethosomes for enhanced skin permeability and vesicle stability. *International journal of pharmaceutics*. 2021 Jan 5;592:119936.
27. Jijie R, Barras A, Boukherroub R, Szunerits S. Nanomaterials for transdermal drug delivery: beyond the state of the art of liposomal structures. *Journal of Materials Chemistry B*. 2017;5(44):8653-75.
28. Jain S, Patel N, Shah MK, Khatri P, Vora N. Recent advances in lipid-based vesicles and particulate carriers for topical and transdermal application. *Journal of pharmaceutical sciences*. 2017 Feb 1;106(2):423-45.
29. Elsayed MM, Abdallah OY, Naggar VF, Khalafallah NM. Deformable liposomes and ethosomes: mechanism of enhanced skin delivery. *International journal of pharmaceutics*. 2006 Sep 28;322(1-2):60-6.
30. Rizwan M, Aqil M, Talegaonkar S, Azeem A, Sultana Y, Ali A. Enhanced transdermal drug delivery techniques: an extensive review of patents. *Recent patents on drug delivery & formulation*. 2009 Jun 1;3(2):105-24.
31. Natsheh H, Touitou E. Phospholipid vesicles for dermal/transdermal and nasal administration of active molecules: The effect of surfactants and alcohols on the fluidity of their lipid bilayers and penetration enhancement properties. *Molecules*. 2020 Jun 27;25(13):2959.



**Mashaerabdelazim Ibrahim Bakhit et al.,**

32. Paiva-Santos AC, Silva AL, Guerra C, Peixoto D, Pereira-Silva M, Zeinali M, Mascarenhas-Melo F, Castro R, Veiga F. Ethosomes as nanocarriers for the development of skin delivery formulations. *Pharmaceutical research*. 2021 Jun;38(6):947-70.
33. Zeb A, Arif ST, Malik M, Shah FA, Din FU, Qureshi OS, Lee ES, Lee GY, Kim JK. Potential of nanoparticulate carriers for improved drug delivery via skin. *Journal of pharmaceutical investigation*. 2019 Sep 1;49:485-517.
34. Akhtar N, Varma A, Pathak K. Ethosomes as vesicles for effective transdermal delivery: from bench to clinical implementation. *Current clinical pharmacology*. 2016 Aug 1;11(3):168-90.
35. Hariharanb S, Justinc A. Topical delivery of drugs using ethosomes: A review. *Indian drugs*. 2019 Sep;56(08):7.
36. Thadanki M, Babu AK. Review on Ethosomes: A novel approach of Liposomes. *International Journal of Pharmacy & Life Sciences*. 2015 Jan 1;6(1).
37. Vijayakumar R. *Formulation and evaluation of diclofenac potassium ethosomes* (Doctoral dissertation, Madurai Medical College, Madurai).
38. Yu YQ, Yang X, Wu XF, Fan YB. Enhancing permeation of drug molecules across the skin via delivery in nanocarriers: novel strategies for effective transdermal applications. *Frontiers in bioengineering and biotechnology*. 2021 Mar 29;9:646554.
39. Rizwan M, Aqil M, Talegaonkar S, Azeem A, Sultana Y, Ali A. Enhanced transdermal drug delivery techniques: an extensive review of patents. *Recent patents on drug delivery & formulation*. 2009 Jun 1;3(2):105-24.
40. Phatale V, Vaiphei KK, Jha S, Patil D, Agrawal M, Alexander A. Overcoming skin barriers through advanced transdermal drug delivery approaches. *Journal of controlled release*. 2022 Nov 1;351:361-80.
41. Sala M, Diab R, Elaissari A, Fessi H. Lipid nanocarriers as skin drug delivery systems: Properties, mechanisms of skin interactions and medical applications. *International journal of pharmaceutics*. 2018 Jan 15;535(1-2):1-7.
42. Mishra KK, Kaur CD, Verma S, Sahu AK, Dash DK, Kashyap P, Mishra SP. Transethosomes and nanoethosomes: Recent approach on transdermal drug delivery system. *Nanomedicine*. 2019 Feb 13;2:33-54.
43. Gorde N, Waghulde SO, Khariche A, Kale M. Vesicular Drug Delivery in Arthritis Treatment. *Advances in Novel Formulations for Drug Delivery*. 2023 Mar 27:177-95.
44. Andreu V, Arruebo M. Current progress and challenges of nanoparticle-based therapeutics in pain management. *Journal of Controlled Release*. 2018 Jan 10;269:189-213.
45. Akhtar N, Verma A, Pathak K. Topical delivery of drugs for the effective treatment of fungal infections of skin. *Current pharmaceutical design*. 2015 Jun 1;21(20):2892-913.
46. Xu C, Wu Y, Zhao L, Zhou W, Li Y, Yi X, Wang Y, Zhang Q, Hu H, Wang Z. Transdermal hormone delivery: Strategies, application and modality selection. *Journal of Drug Delivery Science and Technology*. 2023 Jul 4:104730.
47. Raina N, Rani R, Thakur VK, Gupta M. New Insights in Topical Drug Delivery for Skin Disorders: From a Nanotechnological Perspective. *ACS omega*. 2023 May 19.
48. Andreu V, Arruebo M. Current progress and challenges of nanoparticle-based therapeutics in pain management. *Journal of Controlled Release*. 2018 Jan 10;269:189-213.
49. Sharma A, Kuhad A, Bhandari R. Novel nanotechnological approaches for treatment of skin-aging. *Journal of tissue viability*. 2022 Aug 1;31(3):374-86.
50. Kumar L, Utreja P. Transcending the Cutaneous Barrier Through Nanocarrier Exploration for Passive Delivery of Anti-hypertensive Drugs: A Critical Review. *Recent Patents on Nanotechnology*. 2020 Sep 1;14(3):193-209.
51. Das Kurmi B, Tekchandani P, Paliwal R, Rai Paliwal S. Transdermal drug delivery: opportunities and challenges for controlled delivery of therapeutic agents using nanocarriers. *Current drug metabolism*. 2017 May 1;18(5):481-95.
52. Li N, Qin Y, Dai D, Wang P, Shi M, Gao J, Yang J, Xiao W, Song P, Xu R. Transdermal delivery of therapeutic compounds with nanotechnological approaches in psoriasis. *Frontiers in Bioengineering and Biotechnology*. 2022 Jan 24;9:804415.
53. Chandra J, Hasan N, Nasir N, Wahab S, Thanikachalam PV, Sahebkar A, Ahmad FJ, Kesharwani P. Nanotechnology-empowered strategies in treatment of skin cancer. *Environmental Research*. 2023 Oct 15;235:116649.



**Mashaerabdelazim Ibrahim Bakhit et al.,**

54. Polaka S, Makwana V, Vasdev N, Sheth A, Rajpoot K, Sengupta P, Tekade RK. Engineering immunity via skin-directed drug delivery devices. *Journal of Controlled Release*. 2022 May 1;345:385-404.
55. Bandopadhyay S, Manchanda S, Chandra A, Ali J, Deb PK. Overview of different carrier systems for advanced drug delivery. *InDrug Delivery Systems 2020 Jan 1* (pp. 179-233). Academic Press.
56. Phatale V, Vaiphei KK, Jha S, Patil D, Agrawal M, Alexander A. Overcoming skin barriers through advanced transdermal drug delivery approaches. *Journal of controlled release*. 2022 Nov 1;351:361-80.
57. Uchechi O, Ogbonna JD, Attama AA. Nanoparticles for dermal and transdermal drug delivery. *Application of nanotechnology in drug delivery*. 2014 Jul 25;4:193-227.
58. Paiva-Santos AC, Silva AL, Guerra C, Peixoto D, Pereira-Silva M, Zeinali M, Mascarenhas-Melo F, Castro R, Veiga F. Ethosomes as nanocarriers for the development of skin delivery formulations. *Pharmaceutical research*. 2021 Jun;38(6):947-70.
59. Mbah CC, Builders PF, Attama AA. Nanovesicular carriers as alternative drug delivery systems: ethosomes in focus. *Expert opinion on drug delivery*. 2014 Jan 1;11(1):45-59.
60. Singh D, Kurmi BD, Singh A. Recent advances in nanocarrier-based approaches to atopic dermatitis and emerging trends in drug development and design. *Current Drug Delivery*. 2024.
61. Bimbrawh S, Chopra S, Ansari MJ, Alrobaian M, Almalki WH, Alharbi KS, Alenezi SK, Kaur R, Beg S, Bhatia A. Biocompatible phospholipid-based nanovesicular drug delivery system of ketoprofen: Systematic development, optimization, and preclinical evaluation. *Biotechnology and Applied Biochemistry*. 2023 Feb;70(1):51-67.
62. Dubey V, Mishra D, Jain NK. Melatonin loaded ethanolic liposomes: physicochemical characterization and enhanced transdermal delivery. *European Journal of Pharmaceutics and Biopharmaceutics*. 2007 Sep 1;67(2):398-405.
63. Fernández-García R, Lalatsa A, Statts L, Bolás-Fernández F, Ballesteros MP, Serrano DR. Transferosomes as nanocarriers for drugs across the skin: Quality by design from lab to industrial scale. *International journal of pharmaceutics*. 2020 Jan 5;573:118817.
64. Vipanchi V, Fatima M, Domaraju P. Quality by Design approach for nanosystem based topical drug delivery. *German Journal of Pharmaceutics and Biomaterials*. 2023 Apr 18;2(1):1-7.
65. Akombaetwa N, Ilangala AB, Thom L, Memvanga PB, Witika BA, Buya AB. Current Advances in Lipid Nanosystems Intended for Topical and Transdermal Drug Delivery Applications. *Pharmaceutics*. 2023 Feb 15;15(2):656.
66. Khan SU, Ullah M, Saeed S, Saleh EA, Kassem AF, Arbi FM, Wahab A, Rehman M, ur Rehman K, Khan D, Zaman U. Nanotherapeutic approaches for transdermal drug delivery systems and their biomedical applications. *European Polymer Journal*. 2024 Feb 6:112819.
67. Keservani RK, Bandopadhyay S, Bandyopadhyay N, Sharma AK. Design and fabrication of transdermal/skin drug-delivery system. *InDrug Delivery Systems 2020 Jan 1* (pp. 131-178). Academic Press.
68. Paiva-Santos AC, Silva AL, Guerra C, Peixoto D, Pereira-Silva M, Zeinali M, Mascarenhas-Melo F, Castro R, Veiga F. Ethosomes as nanocarriers for the development of skin delivery formulations. *Pharmaceutical research*. 2021 Jun;38(6):947-70.
69. Ramachandran Chelliah IK, Wei S, Madar IH, Sultan G, Daliri EB, Swamidoss C, Oh DH. Intelligent Packaging Systems: Food Quality and Intelligent Medicine Box Based on Nano-sensors. *Smart Nanomaterials in Biomedical Applications*..555.





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Table 1: Overview of Transdermal Drug Delivery Systems (TDDS):

Feature	Description
Methodology	Delivering medications through the skin's layers directly into the systemic circulation.
Advantages	Non-invasiveness, improved patient compliance, steady drug plasma concentrations, bypassing the gastrointestinal tract, avoiding first-pass metabolism.
Technological Advancements	Development of patches, gels, and nanoparticles, specifically ethosomal nanoparticles, to overcome the skin's stratum corneum barrier.
Importance of Ethosomal Nanoparticles	Enhance drug bioavailability, particularly beneficial for drugs with poor oral bioavailability or those susceptible to hepatic metabolism, can target drug action to specific sites as needed.

Table 2: Challenges Posed by Skin's Barrier to TDDS:

Challenge	Description
Lipophilic Nature	Skin's lipophilic nature favors permeation of small lipophilic molecules while hindering large hydrophilic compounds.
Intercellular Lipid Matrix	Acts as a barrier limiting the diffusion of most substances.
Rate of Drug Release and Penetration	Ensuring controlled and sustained release without causing irritation or sensitization.
Individual Variability	Skin's variability among individuals due to factors like age, skin type, and presence of conditions affects TDDS performance.
Innovative Strategies Required	Use of chemical enhancers, physical methods like microneedles, and novel carriers like ethosomal nanoparticles to improve skin permeability and drug transport.

Table 3: Examples of Drugs Formulated with Ethosomal Nanoparticles for Enhanced Transdermal Delivery:

Drug	Category	Ethosomal Formulation Benefits
Diclofenac	Anti-inflammatory (NSAID)	Enhanced skin permeation and retention compared to conventional formulations, offering localized relief with reduced systemic side effects, beneficial for treating conditions like arthritis.
Lidocaine	Local anesthetic	Superior skin permeation providing rapid onset of anesthesia, beneficial for pain management and minor surgical procedures.
Ketoconazole	Antifungal medication	Improved penetration through the skin, enhancing the treatment of fungal infections by achieving higher drug concentrations at the site of infection.
Testosterone	Hormone	Offers a convenient and consistent method of hormone replacement therapy, avoiding fluctuations in hormone levels associated with other routes.
Estradiol	Hormone	Facilitates consistent hormone delivery for hormone replacement therapy, avoiding fluctuations associated with other routes.

Table 4: Ethosomal Nanoparticles in Transdermal Drug Delivery:

Aspect	Description
Definition	Soft, malleable vesicles composed of phospholipids, high concentrations of ethanol, and water, capable of encapsulating a wide range of therapeutic molecules.
Mechanism of Action	Ethanol disrupts the lipid organization of the stratum corneum, increasing its fluidity and permeability, which facilitates deeper penetration of the encapsulated drug into the skin layers. Phospholipid composition enhances integration with skin's lipid bilayers, improving drug





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	delivery and bioavailability.
Versatility	Capable of encapsulating lipophilic and hydrophilic drugs, peptides, and biological molecules, offering a broad range of applications in transdermal drug delivery.
Comparative Advantages	Ethosomes exhibit superior skin penetration capabilities compared to traditional liposomes due to their ethanol content, which enhances their fluidity and interaction with skin lipids. They offer a non-invasive, patient-friendly alternative to traditional drug delivery methods, potentially improving patient compliance and treatment outcomes.
Future Potential	Integration with personalized medicine and wearable technology for tailored and responsive drug delivery, exploring targeting capabilities by functionalizing the surface of ethosomes, and utilizing smart release systems that respond to environmental or biological stimuli for controlled, site-specific drug release.





Molecular Docking Study on Anti Diarrhoeal Activity of Notchi Karpam - A Siddha Formulation

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ABSTRACT

Siddha medicine is one of the ancient traditional medicine systems of India. In Siddha, Karpam medicine (Rejuvenation) is meant for general well being and treating the specific disease conditions and also for prevention. Based on the composition It has divided into Mooligai karpam, Thathu karpam and Jeeva karpam. 'Notchi karpam' (NK) is a herbal formulation consisting of Notchi (*Vitex negundo*), Chukku (*Zingiber officinale*), Sugar and Ghee. The herb Notchi is mentioned as a vermifuge, febrifuge, expectorant, diuretic and astringent. Chukku is described as a stimulant, stomachic and carminative. Diarrhoea is the passage of 3 or more loose stools per day, or more frequently than normal for the individual. NK is indicated as an anti diarrhoeal in Siddha. *In silico* molecular docking analysis targeting M3 muscarinic acetylcholine receptor and NK constituents. NK is indicated as an anti diarrhoeal and tonic in Siddha Materia Medica. The ingredients of the NK have also been separately mentioned for diarrhoea. The molecular docking study indicated that the bioactive compounds of NK showed a better binding affinity with M3 muscarinic acetylcholine receptors. This study helps to understand the anti diarrhoeal activity of Notchi karpam through the molecular docking study. The results of this study recommended that NK has significant compounds that may exert anti diarrhoeal activity.

Keywords: Siddha formulation, Notchi karpam, Karpam medicine, Anti diarrhoeal.





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INTRODUCTION

Diarrhoea is one of the main cause of death in children under five years old. It is both preventable and treatable. Diarrhoea is a leading cause of malnutrition in children under five years old [10]. Nowadays it is more common to get affected by digestive illness. Food and lifestyle modification is plays a major role. Yogam is about yoga therapy, yogic diet, yogic counseling and Siddha way of lifestyle modification. The kayakarpam medicines were broadly classified into three subtypes based on their origin of the formulation. The principle of kayakarpam (Rejuvenation) is to hold back aging and improve lives. Yogam and Kayakarpam medicines were used for rejuvenation. Among the types of kayakarpam, Notchi karpam(NK) is a Mooligai karpam. NK is composed of *Vitex negundo* (Notchi), *Zingifer officinale* (Dried ginger), Sugar and Ghee. It is mentioned for diaarhoea and as a tonic. The specific components of NK also mentioned for diarrhoea in Siddha materia medica. The herb Notchi is mentioned as a vermifuge, febrifuge, expectorant, diuretic and astringent. Dried ginger is indicated as a stimulant, stomachic and carminative. A total of 104 cited articles on VN were retrieved from major databases and scholarly publishers. Consequently, 120 chemicals that were extracted from VN can be primarily categorized into four classes: flavonoids, lignans, terpenoids and steroids. The extracts and purified compounds of VN exposed assured bioactivities, including anti-nociceptive, hepatoprotective, anti-oxidant, anti-hyperglycemic, anti-tumor, insecticidal, anti-osteoporotic, antimicrobial, anti-androgenic, anti-cataract and antiinflammatory activity [9].

OBJECTIVE

The function is inhibited by forming a hydrogen bond with the amino acids (Ser151, Tyr529, Tyr506, and Trp503) of the M3 muscarinic acetylcholine receptor (PDB –4U14) which is responsible for motility and peristalsis which intervenes the diarrheal activity. Thereby phyto components which inhibit the target muscarinic acetylcholine receptor by occupying the residual active amino acids could preferably block the intestinal motility and thereby establish the anti-diarrhoeal activity.

MATERIALS AND METHODS ^{1,4}

Docking calculations were carried out for retrieved phyto components against target enzyme M3 muscarinic acetylcholine receptor. AutoDock tools were employed to add essential hydrogen atoms, Kollman-united atom type charge, and solvation parameters (Morris, Goodsell et al., 1998)². Affinity (grid) maps of $\times \times \text{ \AA}$ grid points and 0.375 \AA spacing were generated using the Autogrid program². Van der Waals and electrostatic terms were calculated using AutoDock parameter set- and distance-dependent dielectric functions respectively. Simulations for docking were carried out employing the Lamarckian genetic algorithm (LGA) and the Solis & Wets local search technique. (Solis and Wets, 1981)³. The ligand molecules' initial orientation, position, and torsions got randomly selected. During docking, all rotating torsions were liberated. Every docking experiment was the outcome of two distinct runs that were scheduled to conclude after an upper limit of 250000 energy analyses. The population size was set to 150. During the search, quaternion and torsion steps of 5 and a translational step of 0.2 \AA was applied.

INFERENCE

The bioactive lead compounds Friedelin, β -pinene, Vitexin, Gingerenone-A, Gingerol, Apigenin, Orientin and Linoleic acid were retrieved from the ingredients of Notchi karpam. As per the reported data, the leads such as Orientin, Linoleic acid, β -pinene, Vitexin, Gingerenone-A and Gingerol possess significant binding efficacy by interacting with the core target amino acids (Ser151, Tyr529, Tyr506, and Trp503) present on the target with 100% binding efficacy with the target receptor M3 muscarinic acetylcholine receptor -PDB- 4U14.





CONCLUSIONS

Based on the results of the in silico analysis it was evident that the bio-active compound's like Orientin, Linoleic acid, β -pinene, Vitexin, Gingerenone-A and Gingerol present in the herbal ingredients reveal significant binding against the target receptor. Hence it was concluded that these compounds may exert promising anti-diarrhoeal activity by hindering the activity of M3 muscarinic acetylcholine receptor present in the intestinal region that mediates the diarrhoea.

REFERENCES

1. Bikadi, Z., Hazai, E. Application of the PM6 semi-empirical method to modeling proteins enhances docking accuracy of AutoDock. *J. Cheminf.* 1, 15 (2009)
2. T. A. Halgren. *Merck molecular force field. I. Basis, form, scope, parametrization, and performance of MMFF94.* *Journal of Computational Chemistry* 17 (5-6), 490-519 (1998)
3. G. M. Morris, D. S. Goodsell, et al. *Automated docking using a Lamarckian genetic algorithm and an empirical binding free energy function.* *Journal of Computational Chemistry* 19 (14), 1639-1662(1998)
4. F. J. Solis and R. J. B. Wets. *Minimization by Random Search Technique*
5. Suganthi N. Phytochemical constituents and pharmacological activities of *Vitexnegundo* Linn. *Journal of Chemical and Pharmaceutical Research*, 2016, 8(2):800-807
6. Rampogu S, Baek A, Gajula RG, et al. Ginger (*Zingiber officinale*) phytochemicals-gingerenone-A and shogaol inhibit SaHPPK: molecular docking, molecular dynamics simulations and in vitro approaches. *Ann ClinMicrobiolAntimicrob.* 2018;17(1):16.
7. Singh, A., Lal, U. R., Mukhtar, H. M., Singh, P. S., Shah, G., & Dhawan, R. K. (2015). Phytochemical profile of sugarcane and its potential health aspects. *Pharmacognosy reviews*, 9(17), 45–54. <https://doi.org/10.4103/0973-7847.15634>
8. Carolina pena-serna. Chemical, physicochemical, microbiological and sensory characterization of cow and buffalo ghee. *Food Sci. Technol, Campinas*, 40(2): 444-450.2020
9. Zheng CJ, Li HQ, Ren SC, Xu CL, Rahman K, Qin LP, Sun YH. Phytochemical and Pharmacological Profile of *Vitex negundo*. *Phytother Res.* 2015 May;29(5):633-47. doi: 10.1002/ptr.5303. Epub 2015 Jan 30. PMID: 25641408.
10. Stuart H. Ralston, Davidson's principles and practice of Medicine, Elsevier, 23rd edition.

Table 1

PDB	Name of the Target
4U14	M3 muscarinic acetylcholine receptor

Table 2: List Of Phyto Components Selected For Docking

Herbs	Bioactive Compounds
<i>Vitex negundo</i> ⁵	<ul style="list-style-type: none"> ● Friedelin ● β-pinene ● Vitexin
<i>Zingiber officinale</i> ⁶	<ul style="list-style-type: none"> ● Gingerenone-A ● 6 Gingerol
<i>Saccharum officinarum</i> ⁷	<ul style="list-style-type: none"> ● Apigenin ● Orientin





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Cow ghee ⁸	• Linoleic acid
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Table 3: Ligand Properties of compounds That Were Selected for Docking Analysis

Compound	Molar weight g/mol	Molecular Formula	H Bond Donor	H Bond Acceptor	Rotatable bonds
Friedelin	426.7 g/mol	C ₃₀ H ₅₀ O	0	1	0
Beta Pinene	136.23 g/mol	C ₁₀ H ₁₆	0	0	0
Vitexin	432.4 g/mol	C ₂₁ H ₂₀ O ₁₀	7	10	3
Gingerenone-A	356.4 g/mol	C ₂₁ H ₂₄ O ₅	2	5	9
Gingerol	294.391g/mol	C ₁₇ H ₂₆ O ₄	2	4	10
Apigenin	622.5 g/mol	C ₂₇ H ₂₆ O ₁₇	9	17	7
Orientin	448.4 g/mol	C ₂₁ H ₂₀ O ₁₁	8	11	3
Linoleic acid	280.452 g/mol	C ₁₈ H ₃₂ O ₂	1	2	14
Loperamide	477 g/mol	C ₂₉ H ₃₃ ClN ₂ O ₂	1	3	7

Table 4: An overview of the molecular docking studies of the compounds against M3 muscarinic acetylcholine receptor -PDB- 4U14

Compounds	Est. Free Energy of Binding	Est. Inhibition Constant, Ki	Electrostatic Energy	Total Intermolec. Energy	Interact. Surface
Friedelin	-8.65 kcal/mol	453.42 nM	-0.19 kcal/mol	-8.65 kcal/mol	859.096
β-pinene	-5.98 kcal/mol	41.69 uM	-0.01 kcal/mol	-5.98 kcal/mol	417.94
Vitexin	-7.62 kcal/mol	2.58 uM	-0.14 kcal/mol	-7.46 kcal/mol	861.65
Gingerenone-A	-9.98 kcal/mol	48.24 nM	-0.18 kcal/mol	-10.53 kcal/mol	777.297
Gingerol	-7.80 kcal/mol	1.93 uM	-0.07 kcal/mol	-9.49 kcal/mol	760.054
Apigenin	-6.59 kcal/mol	14.84 uM	-0.11 kcal/mol	-8.20 kcal/mol	708.437
Orientin	-7.73 kcal/mol	2.16 uM	-0.22 kcal/mol	7.17 kcal/mol	870.15
Linoleic acid	-7.71 kcal/mol	2.23 uM	-0.05 kcal/mol	-10.57 kcal/mol	692.122
Loperamide	-7.57 kcal/mol	2.84 uM	-0.15 kcal/mol	-7.57 kcal/mol	585.278





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Table 5: Amino acid Residue Interaction of Lead and Standard against M3 muscarinic acetylcholine receptor - PDB- 4U14

Compounds	Inter-action	Amino acid Residues															
		116 ILE	147 ASP	148 TYR	151 SER	199 TRP	225 ILE	231 THR	234 THR	235 ALA	503 TRP	506 TYR	507 ASN	510 VAL	529 TYR	532 CYS	533 TYR
Friedelin	3																
β -pinene	4																
Vanillin	4																
Ginsenoside-A	4																
Gingerol	4																
δ -pinene	2																
Quercetin	4																
Linoleic acid	4																
Loperamide	4																

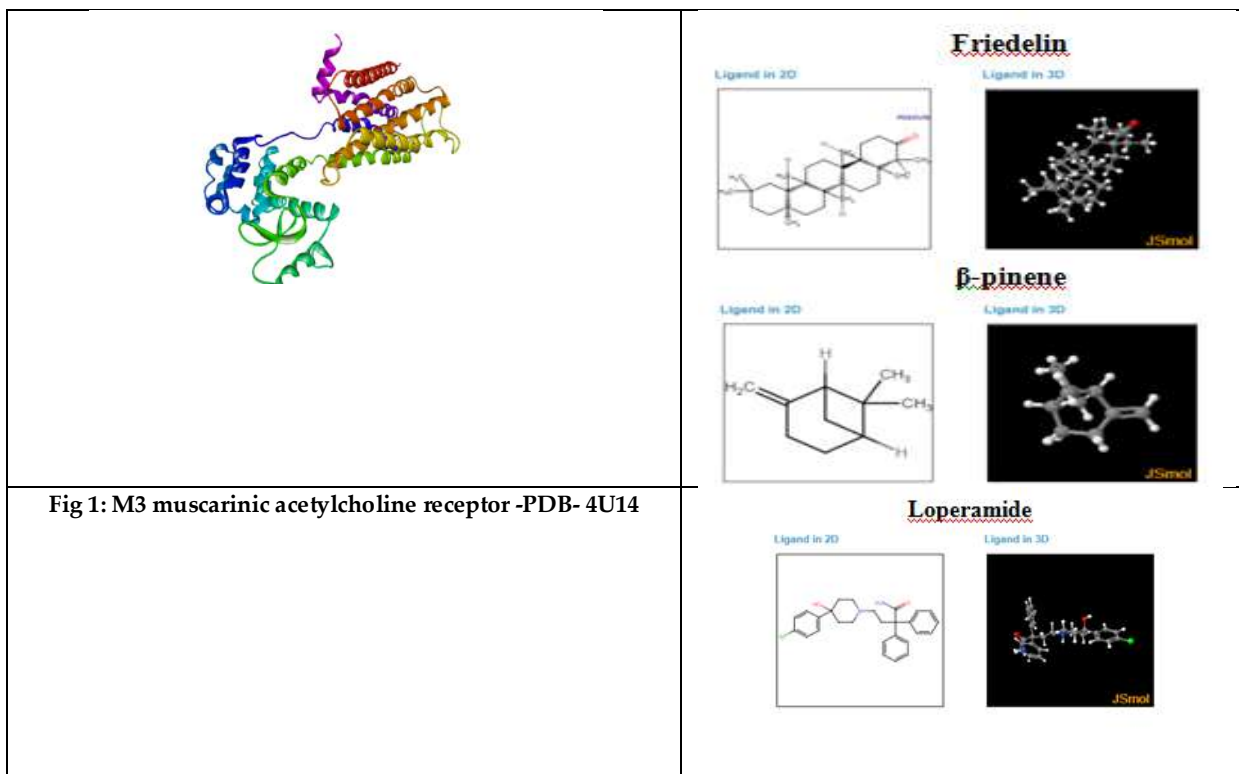


Fig 1: M3 muscarinic acetylcholine receptor -PDB- 4U14





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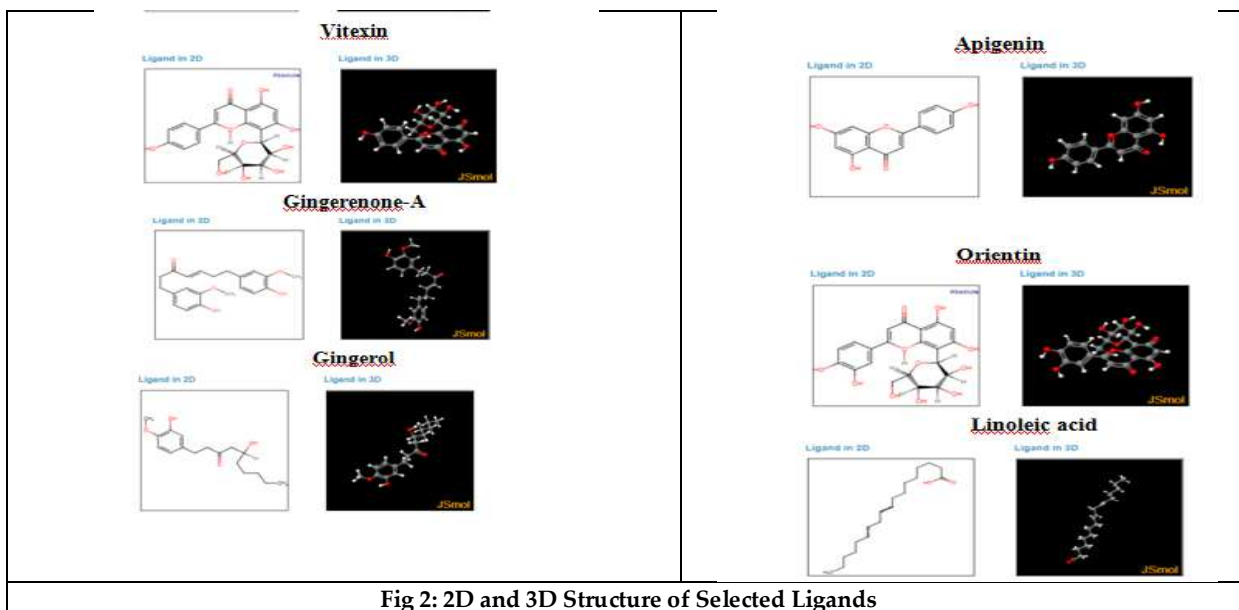


Fig 2: 2D and 3D Structure of Selected Ligands





Anticataract and Aldose Reductase Enzyme Inhibition Potential of the Siddha Formulation *Ilaneer Kuzhambu* on Glucose-Induced Cataract Model

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**ABSTRACT**

Cataract which causes opacification of the lens is the foremost reason for blinding, accounting for above 51% of the global burden. Cataract sightlessness affects over 65 million individuals globally, with 28,000 new cases diagnosed every day. Cataract affects around 25% of the elderly population (above 65 yrs) and 50 % of persons above 80 years. Even though cataract surgery is simple and safe, it may also have some complications such as retinal detachment. Hence, considering an effective yet low-cost alternative for managing this ocular disease seems to be very much needed at this hour. Siddha medicine pioneered the treatment of inflammation and other degenerative conditions; the majority of Siddha proration is made up of botanical substances with new therapeutic properties. Herbal supplements are well-known for their high safety index. The primary objective of this study is to explore the potential of the Siddha formulation IlaneerKuzhambu (IK) in preventing cataract development induced by glucose in an isolated goat lens preparation. Additionally, the study aims to evaluate the formulation's ability to inhibit aldose reductase enzyme activity. The study's findings indicate that the goat lens in group I maintained its average transparency with a high visibility score of 52.8 ± 4.49 . The lens belonging to group II has shown complete cataractogenesis with total loss of transparency and the corresponding visibility score was 9.8 ± 1.92 , significantly lower than group I. Improved visibility was observed in the lens belonging to group III incubated with 100 μ l of the test drug with a score of 17.6 ± 2.07 similarly lens of group IV with 200 μ l showed a significantly higher level of visibility score with 25.4 ± 3.57 . IK showed significant inhibition of the aldose reductase enzyme with a maximum inhibition of about $44.31 \pm 9.016\%$, and the corresponding IC₅₀ is 530.7 ± 40.28 μ l / ml. The current study results indicate that the use of the Siddha formulation IK may have potential in the therapeutic treatment of cataracts in older adults.

Keywords: Siddha formulation, herbal supplements, cataractogenesis, cataract, anticataract

INTRODUCTION

Cataracts, which cause impaired or hazy vision, are a major contributor to avoidable blindness worldwide [1]. Studies indicate that cataracts affect about one-third of 32.4 million blind individuals and 35.1 million among 191 million persons with decreased vision worldwide [2]. After the age of 40, the prevalence of cataracts increases dramatically and the percentage increases with age showing 92.6% amongst those at 80 years and above [3,4]. In the United States, the quantity of individuals with cataracts is expected to quadruple from 24.4 to 50 million by 2050 [5]. Various risk factors such as age, gender, smoking, exposure to UV radiation, chronic steroid usage, Diabetes mellitus and increased BMI are known to contribute to cataract development [6,7]. As life expectancy increases worldwide, the amount of people with cataracts is expected to rise, particularly in low-income countries with minimum access to cataract surgical procedures, necessitating the development of low-cost pharmaceutical options for disease treatment [8]. Free radicals causing oxidative damage have been a concern in the pathology of cataractogenesis [9]. Delaying the formation of cataracts by about 10 years is estimated to decrease the occurrence of visually disabling cataracts by about 45% [10]. Plants contain a large proportion of natural antioxidants, making them the primary source of these compounds. Antioxidants are found in significant quantities in many plant-based foods, including grains, spices, and essential oils that are commonly added to meat products for sensory appeal. Tea water extract is another source of natural antioxidants and contains numerous components such as catechins, tannins, and flavonoids. Unlike essential oils, it does not have a strong flavour [11]. Some fruits and vegetables are high in antioxidants and phytochemicals. Natural antioxidants include minerals and vitamins that function by means of antioxidant enzymes which have short peptides that can neutralize free radicals and inhibit pro oxidative ions of metals. Protein enzymatic degradation results in the formation of antioxidant peptides [12]. Siddha is an old traditional method used to restore an individual's health and well-being. Despite its long herbal pedigree, current technological advancements have explored the real mechanism through which the medication functions [13]. Herbal remedies include physiologically



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active treatments known as secondary metabolites, which have the ability to prevent the course of a variety of illnesses [14]. In terms of innovation, each Siddha formulation is essentially a combination of many medicinal components, thus the approach to the anticataract mechanism becomes complicated, considerably reducing the possibility of cataractogenesis by its antioxidant activity. During the recent two decades, numerous studies have been encouraged to attempt to determine the causes of cataract. Many different medicines have been investigated for their potential to both postpone the start of cataract and reduce their progression. Despite the significant efforts made, no single agent has been shown to be clinically beneficial for accomplishing this goal [7]. Therefore, the prime goal of the present study is to inspect the efficacy of the Siddha formulation IlaneerKuzhambu (IK) in preventing cataract development induced by glucose in an isolated goat lens preparation. Additionally, the study aims to evaluate the formulation's ability to inhibit the activity of the enzyme, aldose reductase.

MATERIALS AND METHODS**Test Drug Details**

The test drug, IlaneerKuzhambu (IK) is procured from SKM, a GMP-certified company. The manufacturing date of the drug is 01/2023 and its Batch No. is NDA23001.

Anti-cataract Activity**Preparation of extraction**

The drug IK is extracted by the Soxhlet extraction method using ethanol as solvent. The extracted solution is weighed and the various concentrations such as 100 μ l and 200 μ l doses are prepared.

Artificial aqueous humor preparation

Artificial aqueous humor is prepared by the combination of NaCl-140mM, KCL-5mM, MgCl₂-2mM, NAHCO₃-0.5 mM, Na₂HPO₄-0.5mM, CaCl₂-0.4mM and glucose 5.5-mM. It is stored in an aseptic condition with a pH of 7.8. To the culture media, penicillin (32 mg%) and streptomycin (250 mg%) were added in order to prevent bacterial contamination [15]. This artificial aqueous humor is used in storing and transporting goat eyeballs.

Collection and transportation of goat eyeballs

Fresh goat eyeballs were collected promptly after the massacre from the slaughterhouse and stored at 0-4°C during transportation to the research laboratory. The extra-capsular extraction was done to extract the lenses and then incubated them in artificial aqueous humor.

Removal of the lens from goat eyeball

By dissecting the cornea and pupil, the lens was removed from the eyeballs through a surgical procedure.

Treatment group details

The goat eye lenses were grouped into four: Group I was categorized as normal control, Group II as cataract control, and the next two groups, III and IV were incubated with the test drug at 100 μ l and 200 μ l doses.

Incubation of Lens

To induce lens opacification II, III, and IV groups were exposed to 55 mM glucose in the artificial aqueous humor. The lenses were then incubated for 72 hours at 37°C. After the termination of the incubation period, the lenses were macroscopically assessed by putting them on graph paper for opacification development, and the lens opacity was measured by counting the number of visible squares through the lens.

Aldose Reductase inhibitory activity**Preparation of Extract and different fractions of Stock solution**

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The drug IK is extracted by Soxhlet extraction method using ethanol as solvent. The stock solution is prepared and diluted to different fractions (100, 200, 300, 400, and 500 µl) using Phosphate Buffer Saline.

Reaction Mixture Preparation

The reaction mixture is prepared by combining freshly prepared aldose reductase enzyme with varying volumes of the test drug (100, 200, 300, 400, and 500 µl) in 0.067 M buffer (pH 6.2), 0.125 mM NADPH, 400 mM lithium sulfate, and 40 mM xylose. The final volume is made up to 1 ml and the final pH is adjusted to 6.2.

PROCEDURE

The 96-well plate is used to perform the experiment. The different fractions of stock solution are added to the reaction mixture which initiates the reaction for NADP formation. Then, NADP formation was detected by calculating the reduction in absorbance at 340 nm over 3 minutes. The assay was done in triplicate [16]. The results were indicated as percentage inhibition and determined using the below formula:

$$\% \text{ Inhibition} = \left(\frac{\text{Absorbance of control} - \text{absorbance of Test}}{\text{absorbance of control}} \right) \times 100$$

STATISTICAL ANALYSIS

The statistical analysis involved expressing the results as Mean \pm SD and using One-Way Analysis of Variance (ANOVA) to analyze the statistical difference between experimental groups. The Dunnet Multiple comparison tests were then done.

RESULTS**Effect of the drug IK on lens opacity**

From the procedure, it is observed that the lens of the goat eye belonging to group I maintains average transparency with a high visibility score of 52.8 ± 4.49 . The lens belonging to group II, treated with glucose 5.5 mM, has shown complete cataractogenesis with total loss of transparency. The corresponding visibility score was 9.8 ± 1.92 , significantly lower than group I. Improved visibility was observed in the lens belonging to group III incubated with 100µl of the test drug with a score of 17.6 ± 2.07 similarly the lens of group IV set with 200µl showed a significantly higher level of visibility score with 25.4 ± 3.57 . Results were tabulated in Table 1 and represented in figure 1.

Effect of the drug IK on aldose reductase inhibition Activity

In the aldose reductase inhibition activity test, IK showed a significant reduction of the activity of aldose reductase enzyme with the maximum inhibition of about $44.31 \pm 9.016\%$, and the corresponding IC₅₀ are 530.7 ± 40.28 µl/ml as shown in table 2.

DISCUSSIONS

A cataract is a condition of the eye in which the lens clouds, resulting in gradual visual loss. Cataract are frequently connected with aging, since the eye's lens gets clouded as a result of the oxidative stress process, causing vision to blur [17]. Cataract are characterized as senile, juvenile, or congenital based on their age [18]. There are three types of cataracts: senile cataracts, juvenile cataracts, and congenital cataracts [19]. In senile cataracts, the lens opacity is caused by the oxidation process. As the elderly population grows, the prevalence and incidence of senile cataract cases are expected to increase. Presently, the incidence of senile cataract is 3.9% among those aged 55-64 and rises to 92.6% in individuals aged 80 years and older [20,21]. Cataract is caused by elevated glucose levels, which generates superoxide radicals and H₂O, resulting in oxidative stress. This, in turn, triggers the activation of antioxidant enzymes in lens cells [22]. Free radicals produced under oxidative stress produce peroxidation of polyionic lipids,





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leading to lens damage [23]. Hyperosmotic stress-associated oxidative damage is considered the primary cause of cataract formation [24]. Plants have served as an excellent source of medicinal compounds for a long time, with many pharmaceuticals previously derived directly or indirectly from them. Active principles derived from plants encompass a wide range of chemical compounds and have shown efficacy in treating various disorders [25]. In recent times, scientists have taken a keen interest in applying ethnobotanical knowledge to medicinal plant research [26]. Plant components and isolated phytochemicals have been used for thousands of years to prevent and cure a variety of health problems [27]. Researchers examined the morphology of goat lenses and evaluated them based on factors such as lens shape, oedema, and transparency. They found that exposing the lenses to glucose led to significant changes in their transparency. As a result of osmotic swelling and the formation of a mature cataract, there was a complete loss of transparency, as demonstrated by the squares becoming invisible. The severity of cataract was used to predict the effectiveness of the Siddha formulation. From this current experiment, it is noted that the goat lens belonging to group I maintains average transparency with a high visibility score of 52.8 ± 4.49 . The lens belonging to group II, treated with glucose 5.5 mM, has shown complete cataractogenesis with total loss of transparency. The corresponding visibility score was 9.8 ± 1.92 , significantly lower than group I. Improved visibility was observed in the lens belonging to group III incubated with 100 μ l of the test drug with a score of 17.6 ± 2.07 similarly lens of group IV set with 200 μ l showed a significantly higher level of visibility score with 25.4 ± 3.57 . Aldose reductase converts sugar molecules into the alcohol form of their respective sugar molecules via biochemical pathways. Those formed alcohols produce osmotic effects within the lens. Polyols are unable to diffuse out easily or metabolize rapidly, leading to hypertonicity that contributes to cataract formation [28]. Oxidative mechanisms also exhibit a critical role in the formation of cataract. Several ARI have been identified with the potential to prevent cataract formation and delay galactose-induced cataracts in various experimental models [29]. In an acute cataract lens model, ex vivo, herbal extracts were found to attenuate aldose reductase activity, affirming their anti-cataract activity [30]. From the current experiment, it is noted that the Siddha drug, IK showed substantial inhibition of aldose reductase enzyme with the maximum inhibition of about $44.31 \pm 9.016\%$, and the corresponding IC₅₀ is $530.7 \pm 40.28 \mu$ l/ml. These findings from in vitro tests of glucose-induced cataracts and aldose reductase enzyme inhibition activity not only prove the preventive effect of the Siddha formulation IK but also suggest that its antioxidant qualities help prevent cataractogenesis. This suggests that IK might be helpful as a preventative measure or treatment for cataracts.

LIMITATIONS

In this study, the activity of the test drug IK was tested only in the isolated cells which can not be taken as evidence for its efficacy. As cells in the human body are in completely different environments of a complex structure with various pathways and cell communications, this result needs to be confirmed with further studies using animal models and clinical studies.

CONCLUSIONS

Cataract is the main reason for blindness worldwide. In diabetes, lens opacification leading to cataracts is linked to elevated oxidative and hyperosmolar stress levels. Siddha formulations made of herbal ingredients are known for their antioxidant activity. Treatment with Siddha drug IK at both doses reveals a significantly higher level of visibility score with 25.4 ± 3.57 in the treated lens. Further data of the present finding advocates significant inhibition of aldose reductase enzyme with the maximum inhibition of about $44.31 \pm 9.016\%$, and the corresponding IC₅₀ is $530.7 \pm 40.28 \mu$ l/ml. The current study shows that the Siddha formulation IK may expect to reveal promising recovery in patients with cataract and can be suggested for the management of the same in the future with prior validation.





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Additional Information

Disclosures

Human subjects

All authors have confirmed that this study did not involve human participants or tissue.

Animal subjects

All authors have confirmed that this study did not involve animal subjects or tissue.

Conflicts of interest

In compliance with the ICMJE uniform disclosure form, all authors declare the following: Payment/services info: All authors have declared that no financial support was received from any organization for the submitted work.

Financial relationships

All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work.

Other relationships

All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

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REFERENCES

1. Lee, C. C., & Afshari, N. A.: The global state of cataract blindness. *Curr Opin Ophthalmol.* 2017, 28(1):98- 103. 10.1097/ICU.0000000000000340
2. Khairallah, M., Kahloun, R., Bourne, R. et., al: Number of People Blind or Visually Impaired by Cataract Worldwide and in World Regions, 1990 to 2010. *Invest. Ophthalmol. Vis. Sci.* 2015, 56 (11):6762-9. 10.1167/iovs.15-17201
3. Mitchell P., Cumming R. G., Attebo K., et al.: Prevalence of cataract in Australia: the Blue Mountains eye study. *Ophthalmology.* 1997, 104(4):581-8. 10.1016/s0161-6420(97)30266-8
4. Schmetterer L., Koh J., Tan A G., et al.: Ancestry, Socioeconomic Status, and Age-Related Cataract in Asians: The Singapore Epidemiology of Eye Diseases Study, *Ophthalmology.* 2015, 122(11):2169-2178. 10.1016/j.ophtha.2015.06.052
5. Cataracts | National Eye Institute. Accessed: 11/05/2023: <https://www.nei.nih.gov/learn-about-eyehealth/eye-conditions-and-diseases/cataracts>.
6. Gupta S., Selvan V., Agrawal S., et al.: Advances in pharmacological strategies for the prevention of cataract development. *Indian J. Ophthalmol.* 2009, 57(3):175-183. 10.4103/0301-4738.49390
7. Thompson, J., & Lakhani, N. (2015a): Cataracts. *Prim Care Clin Office Pract.* 2015, 42(3):409-23. 10.1016/j.pop.2015.05.012
8. Flessa S., Cataract Surgery in Low-Income Countries: A Good Deal! *Healthcare.* 2022, 10(12):2580. 10.3390/healthcare10122580
9. Cheng, H., Fagerholm, P., & Chylack, L. T.: Response of the lens to oxidative-osmotic stress. *Exp. Eye Res.* 1983, 37(1):11-21. 10.1016/0014-4835(83)90145-8





Srinivasan Moorthiyamma Rajaram et al.,

10. Kupfer C.: Bowman lecture. The conquest of cataract: a global challenge. *Trans OphthalmolSoc U K.* 1985, 104(pt 1):1-10.
11. Lourenço, S., Moldão-Martins, M., & Alves, V. D.: Antioxidants of Natural Plant Origins: From Sources to Food Industry Applications. *Molecules.* 2019, 24(22):4132. 10.3390/molecules24224132
12. Jiang, J., & Xiong, Y. L., Natural antioxidants as food and feed additives to promote health benefits and quality of meat products: A review. *Meat Sci.* 2016, 120:107-117. 10.1016/j.meatsci.2016.04.005
13. Sivaraman D., Evaluation of Anti- Urolithiasis Potential of Indian Medicinal Herbs *Ficus hispida*, *Morinda tinctoria* and *Sapindus emarginatus* by Struvite Crystal Growth Inhibition Assay. *Int. J. Chemtech Res..* 2017, 10(10):436-448.
14. D.Sivaraman, N.Anbu, N.Kabilan, et al.: Exploration of Anti-Urolithiasis Potential of Traditional Siddha Formulations *Amukkara Chooranam* and *Karisalai Karpam Chooranam* by Struvite Crystal Growth Inhibition Assay. *PhcogJ..* 2019, 11(4):683-688. 10.5530/pj.2019.11.108
15. Ganeshpurkar A., Bhadoriya S S., Pardhi P., et al.: In vitro prevention of cataract by Oyster Mushroom *Pleurotus florida* extract on isolated goat eye lens. *Indian J Pharmacol..* 2011, 43(6):667-70.
16. Patel D., Kumar R., Kumar M., et al.: Evaluation of in vitro aldose reductase inhibitory potential of different fraction of *Hybanthus enneaspermus*. *Asian Pac J Trop Med.* 2012, 2(2):134-9. 10.1016/s2221- 1691(11)60207-4
17. Hossain, M. B., Khanom, T., & Islam, M. T: A Study on Prevalence of Cataract and Importance of Cataract Surgery at Tertiary Care Hospital in Bangladesh. *SAS J Med.* 2021, 7:12-14. 10.36347/sasjm.2021.v07i01.004
18. Wale M. Z., Derbew M., Tilahun M., et al.: Cataract and associated factors among adults visiting ophthalmic clinic at Debre Markos comprehensive specialized hospital, northwest Ethiopia. *SAGE Open Med..* 2021, 9:2050312121989636. 10.1177/2050312121989636
19. Huang, L., & Lambert, S. R.: Referral basis for congenital and juvenile cataracts . *J AAPOS.* 2019, 23(4):32. 10.1016/j.jaapos.2019.08.113
20. Suryathi, N.M.A., Jayanegara, W.G., Manuaba, I.B.P. 2020: Characteristics retinometry pre and post cataract surgery on senile cataract patients in Sanglah Hospital, Bali-Indonesia. *Intisari Sains Medis.* 2020, 11(3):1504-1509. 10.15562/ism.v11i3.752
21. Rizki Muliani, Rosdiana Simanjuntak, Siti Jundiah: Correlation Between Smoking Habit Level and Stadium of Senile Cataract at Cataract and Refractive Surgery Clinic of Cicendo Eye Hospital Bandung. *J Med Health.* 2020, 2(5):1-10. 10.28932/jmh.v2i5.1896
22. Langade D., Rao G. P., Girme R C., et al.: In vitro prevention by ACE inhibitors of cataract induced by glucose. *Indian J Pharmacol.* 2006, 38(2):107-110. 10.4103/0253-7613.24615
23. Murata T., Nishida T., Eto S., et al.: Lipid peroxidation in diabetic rat retina. *Metab Pediatr Ophthalmol.* 1981, 5(2):83-7.
24. Ruderman, N., Williamson, J., & Brownlee, M.: *Hyperglycemia, Diabetes, and Vascular Disease: An Overview.* Neil Ruderman, Joseph Williamson, Michael Brownlee (ed): Springer, New York, NY; 1992. 10.1007/978-1-4614-7524-8_1
25. Grover, J., Yadav, S. R., & Vats, V.: Medicinal plants of India with anti-diabetic potential. *J. Ethnopharmacol..* 2002, 81(1):81-100. 10.1016/s0378-8741(02)00059-4
26. Ayyanar, M., & Ignacimuthu, S.: Ethnobotanical survey of medicinal plants commonly used by Kanitribals in Tirunelveli hills of Western Ghats, India. *J. Ethnopharmacol..* 2011, 134(4):851-864. 10.1016/j.jep.2011.01.029
27. Mikael E Pedersen., Henrik T Vestergaard., Suzanne L Hansen., et al.: Pharmacological screening of Malian medicinal plants used against epilepsy and convulsions. *J. Ethnopharmacol..* 2009, 121(3):472-475. 10.1016/j.jep.2008.11.006
28. KINOSHITA, J. H., MEROLA, L. O., & DIKMAK, E.: The accumulation of dulcitol and water in rabbit lens incubated with galactose. *Biochim. Biophys. Acta.* 1962, 62:176-8. 10.1016/0006-3002(62)90508-5
29. Harding, J. J.: Pharmacological Treatment Strategies in Age-Related Cataracts.. *Drugs & Aging.* 1992, 2 (4):287-300. 10.2165/00002512-199202040-00003
30. Rosheni N., Nithya K., Brindha S., et al.: Evaluation of anti-cataract potential of *Abutilon indicum*: An in vitro study. *Indian J. Sci. Res.* 2016, 7(1):81-84.





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Table 1: Effect of test drug on opacity scoring on a number of squares counted on glucose-induced cataract in isolated goat lens

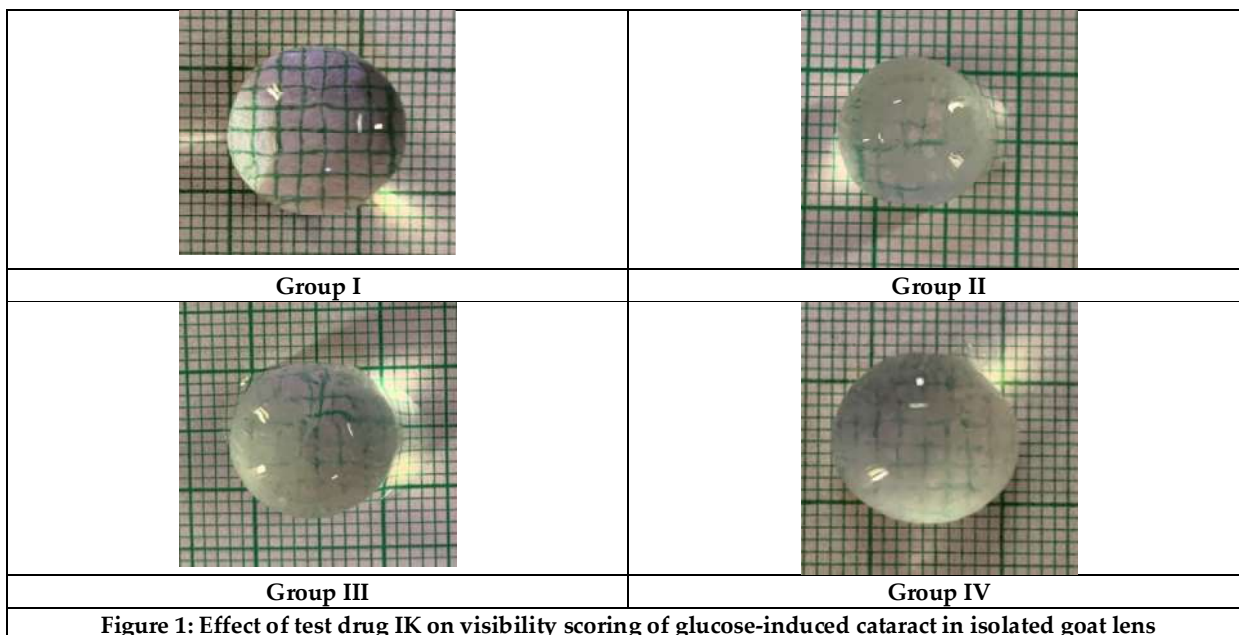
Group	Treatment	Number of Squares Counted (Mean ± SEM)
I	Control	52.8 ± 4.49
II	Negative Control – Only Glucose	9.8 ± 1.92
III	IlaneerKuzhambu (IK) - 100 µl	17.6 ± 2.07
IV	IlaneerKuzhambu (IK) - 200 µl	25.4 ± 3.57

Data expressed as mean ± SD, n=5

Table 2: Percentage inhibition of test drug IK on Aldose reductase enzyme Inhibition assay

Dose in µl	% Inhibition by test drug IK	IC50 Value of Aldose reductase enzyme inhibition by IK
100 µl	11.47 ± 4.29	530.7 ± 40.28
200 µl	18.85 ± 1.01	
300 µl	22.86 ± 2.106	
400 µl	33.81 ± 8.245	
500 µl	44.31 ± 9.016	

Data are represented as Mean ± SD (n=3)





Comprehensive Ayurvedic Management of Diabetic Foot Ulcer – A Case Report

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ABSTRACT

Dushta Vrana mentioned in Ayurveda text resembles with Diabetic foot ulcer (DFU) which is the most typical complication of diabetes mellitus with a poor prognosis and as a result of uncontrolled sugar level there is micro and macro vascular changes occurs. Management of such non healing wound is a big challenge although many modalities like blood-letting, oral medication along with local application and wound debridement have been advocated. This case report deals with a male patient aged 52 years, having a diabetic foot ulcer on the dorsal and lateral aspect of 3rd & 4th digit of right foot adjoining redundant webspace. He had diabetes mellitus type II and was on medication since 2 years. He was started with adjuvant Ayurvedic medicines to control his blood glucose level. The wound managed by Ayurveda with local application of *Jatyadi Ghrita* and Leech therapy near wound site four sitting with interval of seven days. This treatment resulted in complete wound healing within 2 months.

Keywords: *Dushta Vrana*, Diabetic foot ulcer, Wound, *Jatyadi Ghrita*, Leech application





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INTRODUCTION

Prameha Pidika, a disease condition in Ayurvedic literature, can be correlated with diabetic foot ulcer (DFU). [1] It comes under the category of *Dushta Vrana* (Infected wound) as a *Dushchikitsiya* (difficult to manage) entity [2]. As a result of prolonged hyperglycemia the glucose laden tissue leads into multiple changes at neurological, micro-vascular and dermal level. Vascular changes cause ischemia in lower limbs, particularly at foot level which is challenging to treat in diabetes patient [3]. The lifetime risk of a person with diabetes having a foot ulcer has been reported to be as high as 25% [4]. In diabetic ulcer chances of delay in the formation of healthy granulation tissue due to extended inflammatory phase observed in histopathological studies of such ulcers [5]. It is a type of non-healing ulcer which requires surgical intervention in the form of debridement till the wound healed. Amputation is the last choice to treat the Diabetic foot ulcer. Many oral Ayurvedic formulations are there to control diabetes mellitus and DFU along with local treatment. Daily dressing with Ayurvedic formulation results into better wound healing. These formulations also maintain sugar level, eradicate toxins, improve circulation and enhance wound healing [6]. Sushruta has emphasized upon *Shodhana* and *Raktamokshana* for the management of *Madhumehaj Dushta Vrana* [7]. *Raktamokshana* (bloodletting) is advised in painful conditions, swelling and suppuration in *Prameha Pidika* (DFU) [8]. Leech application is the best para surgical modality which can be used in children, females, pregnant patients and elderly [9]. In this type of ulcer patient leech application enhances circulation and results into better wound healing.

CASE REPORT

A male patient aged 52 years, came to the hospital with the complaints of swelling, pus discharge, foul smell and non-healing wound over right side foot at 3rd & 4th digit and redundant web space since 2 years. The patient was known case of diabetes mellitus since two years and was on medication. He was admitted for wound management, his laboratory investigations were within normal limit except random blood sugar 177mg/dl, HbA1c 6.7%, Blood Urea 16.4 mg/dl, Serum Creatinine 1.5 mg/dl. Urine examination revealed proteins, sugar, pus and epithelial cells within normal limit. Expert opinion was taken for renal function and diabetes from the Department of Kayachikitsa (Internal medicine) and managed accordingly.

Local treatment

1. Daily dressing was done with *Jatyadighrita* ointment (an Ayurvedic medicine).
2. One leech applied above the wound once a week for one month (4 sittings). Systemic treatment

DISCUSSION

The *Vrana* (ulcer) which is painful, having a foul smell, discolouration, copious purulent discharge has been termed as *Ashuddha Vrana* or *Dushta Vrana* (Infected/unhealthy wound) and requires *Shodhana* (cleansing) as per Acharya Charaka [10]. *Dushta Vrana* (Infected wound) becomes *Shudha Vrana* (clean wound) after wound debridement, local application of *Jatyadi Ghrita*, leech therapy and Ayurvedic anti-diabetic treatment [11]. As the treatment started the foul smell and pus discharge slowly reduced. The swelling at the foot region also decreased with continuation of the treatment wounds became clean, and signs of healing appeared. Gradually the wound size reduced, and wound margins became bluish, showing the stage of *Rohita Vrana* (healing wound) [12]. The wound healed completely after 2 months of treatment. *Pathya-apathya* (Diet and Lifestyle regimen) were advised to the patient as advocated by Sushruta [13]. Possibly leech application enhances wound healing in two ways; firstly by improving the blood circulation and clearing the micro thrombi and secondly by sucking deoxygenated blood which paves the way for fresh blood. This leads to an increase in the perfusion of blood in the wound area and trigger to release venous congestion in the surrounding area. Suction by leeches creates pressure in the wound area to initiate wound contraction and enhance proliferation of new tissue. Other benefits of leech application are pacifying the glucose level at the cellular level, help to control the rate of infection.





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CONCLUSION

In this case study the potentials of Ayurvedic principles of wound management in diabetic foot ulcer had been proved. The effective and cost-effective management of wound through *Raktamokshana* and local application of drugs are used in this study. Although strict blood sugar control can heal the diabetic foot ulcers without the use of antibiotics. The provision of diabetes related preventive care could potentially be improved by increasing accessibility to diabetes education.

Conflict of interest: All the authors make a declaration that they have no conflict of interest.

Declaration of patient consent: Authors certify that they have obtained consent from the patient and his attendants for the clinical history and images to be reported in the journal while maintaining confidentiality.

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REFERENCES

1. Sushruta. Susrutha Samhitha, Sutrasthana, Krutyakrutavidhi Adhyaya, 23/5-12, edited by Shastri A, 12th ed. Chaukhambha Sanskrit Sansthan, Varanasi. 2013;126-127.
2. Sushruta. Susrutha Samhitha, Chikitsa Sthana, Sadhyovrana Adhyaya, 2/94, edited by Shastri A, ChaukhambhaSanskritaSansthan, Varanasi, 2001; 26.
3. F. Al-Maskari and M. El-Sadig, "Prevalence of risk factors for diabetic foot complications," BMC Family Practice, vol. 8, p. 59, 2007. [Google Scholar].
4. Sinharay K., Paul UK, Bhattacharya AK, Pal SK. Prevalence of diabetic foot ulcers in newly diagnosed diabetes mellitus patients. *J Indian Med Assoc.* 2012;110:608–611. <https://pubmed.ncbi.nlm.nih.gov/23741832/> [PubMed] [Google Scholar].
5. Pierce GF, Mustoe TA. Pharmacologic enhancement of wound healing. *Annu Rev Med* 1995;46:467-81.
6. Hou ZY, Liu CZ. Research advance of topical application of Chinese herbs for the treatment of the diabetic foot. *Jilin Journal of Traditional Chinese Medicine* 2003;23(4):54–5.
7. Sushruta. Susrutha Samhitha, Chikitsa Sthana, Sadhyovrana Adhyaya, 2/86-87, edited by Shastri A, ChaukhambhaSanskritaSansthan, Varanasi, 2001; 26.
8. Sushruta. Susrutha Samhitha, Chikitsa Sthana, Pramehapidika Chikitsa Adhyaya, 12/4, edited by Shastri A, ChaukhambhaSanskritaSansthan, Varanasi, 2001; 79.
9. Susrutha Samhitha, Sutra Sthana, Jaloukaavcharniya Adhyaya, 13/3, edited by Shastri A, Chaukhambha Sanskrita Sansthan, Varanasi, 2001; 59.
10. CharakaSamhita, Chikitsa Sthan, dwivranianyachikitsaAdhyaya, 25/83 by K.N. Shastri and G.N. Chaturvedi, Chaukhamba Sanskrit Sansthan, Varanasi, 1996; 710 .
11. Sushruta. Susrutha Samhitha, Sutra Sthana, KrutyakrutavidhiAdhyaya, 23/18, edited by Shastri A, ChaukhambhaSanskritaSansthan, Varanasi, 2001; 99.
12. Sushruta. Susrutha Samhitha, Sutra Sthana, KrutyakrutavidhiAdhyaya, 23/19, edited by Shastri A, Chaukhambha Sanskrita Sansthan, Varanasi, 2001; 99.
13. Susrutha Samhitha, Sutra Sthana, Vranitoupasaniy Adhyaya, 19/10-36, edited by Shastri A, Chaukhambha Sanskrit Sansthan, Varanasi, 2001; 79-82.





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Table 1: Systemic treatment

Sr.No.	Name of Medicine	Dose
1.	Tab.TriphalaGuggulu	2 tab twice daily after food with luke warm water
2.	Tab. ArogyavardhiniVati	2 tab twice daily after food with luke warm water
3.	Tab. Panch tikta ghrīt guggulu	2 tab twice daily after food with luke warm water





Nano *PRE JD* Continuous and Nano *PRE JD* Irresolute Functions in Nano Topological Spaces

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ABSTRACT

The motive of this study is to expound and discuss a new continuous mapping called Nano *pre JD* continuous maps and a new function called Nano *pre JD* irresolute functions. Basic properties and implications of Nano *pre JD* continuous maps with other existing continuous maps are discussed with fitting examples.

Keywords: Nano Continuous, Nano Irresolute function, Nano *pre JD* open sets, Nano *pre JD* closed sets, Nano topology

MSC 2010: 54A05, 54C10, 54B05

INTRODUCTION

Thivagar.L.M [5] initiated the concept of Nano Topology and in later years he proposed a function called nano continuous functions[4]. In this paper we expound a new continuous mapping and a new irresolute function which relies on Nano *pre JD* open sets[1]. This new continuous map and irresolute function is named as Nano *pre JD* continuous and Nano *pre JD* irresolute function. In the following sections, we use acronym forms like, N.T(Nano Topology); N.T.S(Nano Topological Space); N-o-s or N-o(Nano open set or Nano open); N-c-s or N-c (Nano closed set or Nano closed); N-cont.(Nano continuous).





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PRELIMINARIES

Definition 2.1: Let P be a not-null countable set of objects called the universe and consider R on P to be an equivalence relation. Then (P, R) is approx.space. Let $E \subseteq P$.

i) Form the lower approx. of E subject to R , it is the set of all objects, which can be determined as $L_R(E) = \cup_{E \in U} \{R(e) : R(e) \subseteq E\}$.

ii) Form the upper approx. of E subject to R is the set of all objects, which can be determined as $U_R(E) = \cup_{E \in U} \{R(e) : R(e) \cap E \neq \emptyset\}$

iii) The boundary region of X regard to R is the set of all objects, which can be classified by as $B_R(E) = U_R(E) - L_R(E)$.

Definition 2.2: Here P is known to be universe, R on P is known to be an equivalence relation and $E \subseteq P$. Then $\tau_R(E) = \{P, \emptyset, L_R(E), U_R(E), B_R(E)\}$

If $\tau_R(E)$ holds the following conditions then $\tau_R(E)$ is a topology on P called the N.T on P subject to E : $P, \emptyset \in \tau_R(E)$; Union of any sub collection of sets of $\tau_R(E)$ belongs to $\tau_R(E)$; Intersection of any countable sub collection of the subsets of $\tau_R(E)$ belongs to $\tau_R(E)$.

We call $(P, \tau_R(E))$ as the N.T.S. The sets of $\tau_R(E)$ are N-o-s and the sets of $[\tau_R(E)]^c$ are N-c-s

Definition 2.3: Let $(P, \tau_R(E))$ be a N.T.S and $L \subseteq P$. Then L is said to be N-pre JD open if $L \subseteq \text{Nint}^{JD}(Ncl(L))$.

Definition 2.4: Let $(P, \tau_R(E))$ and $(Q, \tau_{R'}(F))$ be N.T.S. Then the mapping $d: (P, \tau_R(E)) \rightarrow (Q, \tau_{R'}(F))$ is

i) N-cont. if the inverse image of all N-o-s in $(Q, \tau_{R'}(F))$ is N-o in $(P, \tau_R(E))$.

ii) N-semi-cont. if the inverse image of all N-o-s in $(Q, \tau_{R'}(F))$ is N-semi open in $(P, \tau_R(E))$.

iii) N-pre cont. if the inverse image of all N-o-s in $(Q, \tau_{R'}(F))$ is N-pre open in $(P, \tau_R(E))$.

iv) N-JD cont. if the inverse image of all N-o-s in $(Q, \tau_{R'}(F))$ is N-JD open set in $(P, \tau_R(E))$.

N-PRE JD CONT. FUNCTIONS IN N.T.S

Definition 3.1: Let $(P, \tau_R(E))$ and $(Q, \tau_{R'}(F))$ be N.T.S. Then a mapping $d: (P, \tau_R(E)) \rightarrow (Q, \tau_{R'}(F))$ is N-pre JD cont. on P if the inverse image of all N-o-s in $(Q, \tau_{R'}(F))$ is N-pre JD open set in $(P, \tau_R(E))$.

Example 3.2: Let $P = \{1, 2, 3, 4, 5\}$ and $P/R = \{\{1, 2, 3\}, \{4\}, \{5\}\}$ and $E = \{2, 3, 4\}$. Then the N.T $\tau_R(E) = \{P, \emptyset, \{4\}, \{1, 2, 3\}, \{1, 2, 3, 4\}\}$. Let $Q = \{6, 7, 8, 9, 10\}$ and $Q/R' = \{\{6\}, \{10\}, \{8\}, \{7, 9\}\}$ and $F = \{6, 7\}$. Then the N.T $\tau_{R'}(F) = \{\{6\}, \{7, 9\}, \{6, 7, 9\}\}$. Define a mapping $d: (P, \tau_R(E)) \rightarrow (Q, \tau_{R'}(F))$ as $d(1) = 6, d(2) = 7, d(3) = 9, d(4) = 8, d(5) = 10$. Then $d^{-1}(\{6\}) = \{1\}, d^{-1}(\{7, 9\}) = \{2, 3\}, d^{-1}(\{6, 7, 9\}) = \{1, 2, 3\}$. Here the inverse image of all o-s in $\tau_{R'}(F)$ is N-pre JD-o($P, \tau_R(E)$).

Theorem 3.3 : A function $d: (P, \tau_R(E)) \rightarrow (Q, \tau_{R'}(F))$ is N-pre JD cont. if, and only if the inverse image of all N-c-s in Q is N-pre JD-c in P .

For, Let d be N-pre JD cont. and L be N-c in Q . Then, $Q - L$ is N-o in Q . As d is N-pre JD cont., $d^{-1}(Q - L)$ is N-pre JD open in P . For this reason, $d^{-1}(L)$ is N-pre JD closed in P . In consequence, the inverse image of all N-c set in Q is N-pre JD closed in P , take d is N-pre JD cont. on P .

Conversely, let the inverse image of all N-c be N-pre JD closed and let M be N-o in Q . Then $Q - M$ is N-pre JD closed in Q . This implies $d^{-1}(Q - M)$ is N-pre JD closed in P . That is, $P - d^{-1}(M)$ is N-pre JD closed in P . For this reason, $d^{-1}(M)$ is N-pre JD open in P . That is, d is N-pre JD cont. on P .

Theorem 3.4: A function $q: (P, \tau_R(E)) \rightarrow (Q, \tau_{R'}(F))$ is N-pre JD cont. if, and only if $q(Npre JD cl(L)) \subseteq Ncl(q(L))$ for all subset of P .





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For, Let q be N-pre JD cont. and $L \subseteq P$. Then $q(L) \subseteq Q$. As q is N-pre JD cont. and $Ncl(q(L))$ is also N-c in Q , $q^{-1}(Ncl(q(L)))$ is also N-pre JD closed in P .

As $(L \subseteq Ncl(q(L)))$, $q^{-1}(q(L)) \subseteq q^{-1}(Ncl(q(L)))$, then $NpJDcl(L) \subseteq NpJDcl[q^{-1}(Ncl(q(L)))] = q^{-1}(Ncl(q(L)))$. In consequence, $NpJDcl(L) \subseteq q^{-1}(Ncl(q(L)))$. For this reason, $q(NpJDcl(L)) \subseteq Ncl(q(L))$ for all subset L of P . Conversely, $q(NpJDcl(L)) \subseteq Ncl(q(L))$ for all subset L of P . If K is N-c in Q , since $q^{-1}(K) \subseteq P$; $q(NpJDcl(q^{-1}(K))) \subseteq Ncl(q(q^{-1}(K))) = Ncl(K)$. That is, $NpJDcl(q^{-1}(K)) \subseteq q^{-1}(Ncl(K)) = q^{-1}(K)$, since K is N-c. In consequence $NpJDcl(q^{-1}(K)) \subseteq q^{-1}(K)$. For that reason, $q^{-1}(K)$ is N-pre JD-c in P for all N-c set K in Q . That is, q is N-pre JD cont.

Remark 3.5: If $q: (P, \tau_R(E)) \rightarrow (Q, \tau_R(F))$ is N-pre JD cont., then $q(NpJDcl(L))$ need not be equal to $cl(q(L))$.

For instance, Let $P = \{2,4,6\}$ with $P/R = \{\{2\}, \{4,6\}\}$ and $E = \{2,6\}$. Then $\tau_R(E) = \{P, \emptyset, \{2\}, \{4,6\}\}$. Then N-pre JD o-s = $\{P, \emptyset, \{2\}, \{4\}, \{6\}, \{2,4\}, \{2,6\}, \{4,6\}\}$. Let $Q = \{3,5,7\}$ with $Q/R = \{\{3\}, \{5,7\}\}$ and $F = \{7\}$. Then $\tau_R(F) = \{Q, \emptyset, \{5,7\}\}$. Define $q: (P, \tau_R(E)) \rightarrow (Q, \tau_R(F))$ as $q(2) = 5, q(4) = 7, q(6) = 3$. Here $q^{-1}(\{5,7\}) = \{2,4\}$ which is N-pre JD open in P . For this reason, q is N-pre JD cont. on P . Now let $L = \{2,4\} \subseteq P$. Then $q(NpJDcl(L)) = q(NpJDcl(\{2,4\})) = q(\{2,4\}) = \{5,7\}$, But $Ncl(q(L)) = Ncl(q(\{2,4\})) = Ncl(\{5,7\}) = Q$. For this reason, $q(NpJDcl(L)) \neq Ncl(q(L))$ though q is N-pre JD cont.

Theorem 3.6: A function $\delta: (P, \tau_R(E)) \rightarrow (Q, \tau_R(F))$ is N-pre JD cont. if $NpJDcl(\delta^{-1}(L)) \subseteq \delta^{-1}(Ncl(L))$ and conversely.

For, If δ is N-pre JD cont. and $L \subseteq Q$, then $Ncl(L)$ is N-c in Q and hence $\delta^{-1}(Ncl(L))$ is N-pre JD closed in P . For that reason, $NpJDcl(\delta^{-1}(Ncl(L))) = \delta^{-1}(Ncl(L))$. As, $L \subseteq NpJDcl(L)$, $\delta^{-1}(L) \subseteq \delta^{-1}(Ncl(L))$. For this reason $NpJDcl(\delta^{-1}(L)) \subseteq NpJDcl(\delta^{-1}(Ncl(L))) = \delta^{-1}(Ncl(L))$. That is, $NpJDcl(\delta^{-1}(L)) \subseteq \delta^{-1}(Ncl(L))$.

Conversely, let $NpJDcl(\delta^{-1}(L)) \subseteq \delta^{-1}(Ncl(L))$ for all subset L of Q . If L is N-c in Q , then $Ncl(L) = L$. Assuming, $NpJDcl(\delta^{-1}(L)) \subseteq \delta^{-1}(Ncl(L)) = \delta^{-1}(L)$. But $\delta^{-1}(L) \subseteq NpJDcl(\delta^{-1}(L))$. For this reason, $NpJDcl(\delta^{-1}(L)) = \delta^{-1}(L)$. That is $\delta^{-1}(L)$ in P is N-pre JD closed for all N-c set L in Q . For this reason δ is N-pre JD cont. on P .

Remark 3.7: If $\delta: (P, \tau_R(E)) \rightarrow (Q, \tau_R(F))$ is N-pre JD cont., then $\delta(NpJDcl(\delta^{-1}(L)))$ need not be equal to $\delta^{-1}(Ncl(\delta(L)))$.

For instance, Let $P = \{2,4,5,8\}$ with $P/R = \{\{2\}, \{5\}, \{4,8\}\}$ and $E = \{2,4\}$. Then $\tau_R(E) = \{P, \emptyset, \{2\}, \{4,8\}, \{2,4,8\}\}$. Let $Q = \{9,6,3,7\}$ with $Q/R = \{\{9\}, \{7\}, \{6,3\}\}$ and $F = \{9,7\}$. Then $\tau_R(F) = \{V, \emptyset, \{6,3\}\}$. Define $\delta: (P, \tau_R(E)) \rightarrow (Q, \tau_R(F))$ as $\delta(2) = 9, \delta(4) = 6, \delta(5) = 3, \delta(8) = 7$. Here δ is N-pre JD cont. on P since the inverse image of all N-o-s in Q is N-pre JD open in P . Let $L = \{3\} \subseteq Q$. Then $\delta^{-1}(Ncl(L)) = \delta^{-1}(Ncl(\{3\})) = \delta^{-1}(\{Q\}) = P$, But $NpJDcl(\delta^{-1}(L)) = NpJDcl(\delta^{-1}(\{3\})) = NpJDcl(\{5\}) = 5$. For this reason $\delta^{-1}(Ncl(L)) \neq NpJDcl(\delta^{-1}(L))$ though δ is N-pre JD cont.

Theorem 3.8: A function $\omega: (P, \tau_R(E)) \rightarrow (Q, \tau_R(F))$ is N-pre JD cont. if, and only if

$\omega^{-1}(Nint(L)) \subseteq NpJDint(\omega^{-1}(L))$ for all subset L of Q .

For, If ω is N-pre JD cont. and $L \subseteq Q$, then $Nint(L)$ is N-o in Q and $\omega^{-1}(Nint(L))$ is N-pre JD open in P . For this reason, $NpJDint[\omega^{-1}(Nint(L))] = \omega^{-1}(Nint(L))$. Also $Nint(L) \subseteq L$ implies that $\omega^{-1}(Nint(L)) \subseteq \omega^{-1}(L)$. For this reason, $NpJDint(\omega^{-1}(Nint(L))) \subseteq NpJDint(\omega^{-1}(L))$. That is, $\omega^{-1}(Nint(L)) \subseteq NpJDint(\omega^{-1}(L))$.

Conversely, let $\omega^{-1}(Nint(L)) \subseteq NpJDint(L)$ for all $L \subseteq V$. If L is N-o in Q , then $Nint(L) = L$. Assuming, $\omega^{-1}(Nint(L)) = NpJDint(\omega^{-1}(L))$. Thus, $\omega^{-1}(L) \subseteq NpJDint(\omega^{-1}(L))$. But $NpJDint(\omega^{-1}(L)) \subseteq \omega^{-1}(L)$. Therefore, $\omega^{-1}(L) = NpJDint(\omega^{-1}(L))$. That is, $\omega^{-1}(L)$ is N-pre JD open in P for all N-o-s in Q . For this reason, ω is N-pre JD cont. on P .

Remark 3.9: A function $\omega: (P, \tau_R(E)) \rightarrow (Q, \tau_R(F))$ is N-pre JD cont. then $\omega^{-1}(Nint(L))$ need not be equal to $NpJDint(\omega^{-1}(L))$ for all subset L of Q .





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For instance, Let $P = \{4,5,6,7\}$ with $P/R = \{\{4\}, \{6\}, \{5,7\}\}$ and $E = \{4,5\}$. Then $\tau_R(E) = \{P, \emptyset, \{4\}, \{5,7\}, \{4,5,7\}\}$. Let $Q = \{9,8,3,2\}$ with $Q/R' = \{\{9\}, \{2\}, \{8,3\}\}$ and $F = \{9,2\}$. Then $\tau_{R'}(F) = \{Q, \emptyset, \{8,3\}\}$. Define $\omega: (P, \tau_R(E)) \rightarrow (Q, \tau_{R'}(F))$ as $\omega(4) = 9, \omega(5) = 8, \omega(6) = 3, \omega(7) = 2$. Here ω is N-pre JD cont. on P since the inverse image of all N-o-s in Q is N-pre JD open in P . Let $L = \{8\} \subseteq Q$. Then $\omega^{-1}(N \text{ int}(L) = \omega^{-1}(N \text{ int}(\{8\})) = \omega^{-1}(\{\emptyset\}) = \emptyset$, But $N \text{ pJD int}(\omega^{-1}(L)) = N \text{ pJD int}(\omega^{-1}(\{8\})) = N \text{ pJD cl}(\{5\}) = 5$. For this reason $\omega^{-1}(N \text{ int}(L)) \neq N \text{ pJD int}(\omega^{-1}(L))$ though ω is N-pre JD cont.

Theorem 3.10 Consider two N.T.S $(P, \tau_R(E))$ and $(Q, \tau_{R'}(F))$, then for any function $\mu: (P, \tau_R(E)) \rightarrow (Q, \tau_{R'}(F))$ respectively, the following are equivalent conditions

- i. $\mu: (P, \tau_R(E)) \rightarrow (Q, \tau_{R'}(F))$ is N-pre JD cont.
- ii. $\mu(N \text{ pJD cl}(L)) \subseteq N \text{ cl}(\mu(L))$ for each subset L of P
- iii. $N \text{ pJD cl}(\mu^{-1}(L)) \subseteq \mu^{-1}(N \text{ cl}(L))$ for all subset L of Q .

For, (i) \Rightarrow (ii) Let μ be N-pre JD cont. and $L \subseteq P$. Then $\mu(L) \subseteq Q$. Taken μ is N-pre JD cont. and $N \text{ cl}(d(L))$ is N-c in Q , $\mu^{-1}(N \text{ cl}(\mu(L)))$ is N-pre JD closed in P . Since $\mu(L) \subseteq N \text{ cl}(\mu(L))$, $\mu^{-1}(\mu(L)) \subseteq \mu^{-1}(N \text{ cl}(\mu(L)))$; then $N \text{ pJD cl}(L) \subseteq N \text{ pJD cl}(\mu^{-1}(N \text{ cl}(\mu(L)))) = \mu^{-1}(N \text{ cl}(\mu(L)))$. Thus $N \text{ pJD cl}(L) = \mu^{-1}(N \text{ cl}(\mu(L)))$. For this reason, $\mu(N \text{ pJD cl}(L)) \subseteq N \text{ cl}(\mu(L))$ for each subset L of P .

For, (ii) \Rightarrow (iii) Let $\mu(N \text{ pJD cl}(L)) \subseteq N \text{ cl}(\mu(L))$ and $L = \mu^{-1}(L) \subseteq P$ for all subset $L \subseteq Q$. Since $\mu(N \text{ pJD cl}(L)) \subseteq N \text{ cl}(\mu(L))$ we have, $\mu(N \text{ pJD cl}(\mu^{-1}(L))) \subseteq N \text{ cl}(\mu(\mu^{-1}(L))) \subseteq N \text{ cl}(L)$, that is $\mu(N \text{ pJD cl}(\mu^{-1}(L))) \subseteq N \text{ cl}(L)$ which implies that $N \text{ pJD cl}(\mu^{-1}(L)) \subseteq \mu^{-1}(N \text{ cl}(L))$ for all subset $L \subseteq Q$.

For, (iii) \Rightarrow (i) Let $N \text{ pJD cl}(\mu^{-1}(L)) \subseteq \mu^{-1}(N \text{ cl}(L))$ for all subset L of Q . If L is N-c in Q , then $N \text{ cl}(L) = L$. By assumption, $N \text{ pJD cl}(\mu^{-1}(L)) \subseteq \mu^{-1}(N \text{ cl}(L)) = \mu^{-1}(L)$. Thus $N \text{ pJD cl}(\mu^{-1}(L)) \subseteq \mu^{-1}(L)$: But $\mu^{-1}(L) \subseteq N \text{ pJD cl}(\mu^{-1}(L))$. For this reason $N \text{ pJD cl}(\mu^{-1}(L)) = \mu^{-1}(L)$. That is, $\mu^{-1}(L)$ is N-pre JD closed P for all N-c set L in Q . For this reason, μ is N-pre JD cont. on P .

Theorem 3.11: Let $(P, \tau_R(E))$ and $(Q, \tau_{R'}(F))$ be two N.T.S and let the mapping be $d: (P, \tau_R(E)) \rightarrow (Q, \tau_{R'}(F))$, then all N-cont. function is N-pre JD cont. function.

For, Let $d: (P, \tau_R(E)) \rightarrow (Q, \tau_{R'}(F))$ be N-cont. and L be N-o which is in Q . Then $d^{-1}(L)$ is N-o in P . As all N-o set implies N-pre JD open, $d^{-1}(L)$ is N-pre JD open in P . In consequence inverse image of all N-o-s is N-pre JD open. For this reason, d is N-pre JD cont.

Theorem 3.12: Let $(P, \tau_R(E))$ and $(Q, \tau_{R'}(F))$ be two N.T.S and let the mapping be $d: (P, \tau_R(E)) \rightarrow (Q, \tau_{R'}(F))$, then all N-JD cont. function is N-pre JD cont. function.

For, Let $d: (P, \tau_R(E)) \rightarrow (Q, \tau_{R'}(F))$ be N-JD cont. and L be N-JD open which is in Q . Then $d^{-1}(L)$ is N-JD open in P . As all N-JD open set implies N-pre JD open, $d^{-1}(L)$ is N-pre JD open in P . In consequence inverse image of all N-JD open set is N-pre JD open. For this reason, d is N-pre JD cont.

Theorem 3.13: Let $(P, \tau_R(E))$ and $(Q, \tau_{R'}(F))$ be two N.T.S and let the mapping be $d: (P, \tau_R(E)) \rightarrow (Q, \tau_{R'}(F))$, then every Nano g cont. function is Nano pre JD cont. function.

For, Let $d: (P, \tau_R(E)) \rightarrow (Q, \tau_{R'}(F))$ be N-g cont. and L be N-g open which is in Q . Then $d^{-1}(L)$ is N-g-o in P . As all N-g open set is N-pre JD open, $d^{-1}(L)$ is N-pre JD open in P . In consequence inverse image of all N-g open set implies N-pre JD open. For this reason, d is N-pre JD cont.

Theorem 3.14: Let $(P, \tau_R(E))$ and $(Q, \tau_{R'}(F))$ be two N.T.S and let the mapping be $d: (P, \tau_R(E)) \rightarrow (Q, \tau_{R'}(F))$, then all N-regular cont. function is N-pre JD cont. function.

For, Let $d: (P, \tau_R(E)) \rightarrow (Q, \tau_{R'}(F))$ be N-regular cont. and L be N-regular open which is in Q . Then $d^{-1}(L)$ is N-regular open in P . As all N-regular open set is N-pre JD open, $d^{-1}(L)$ is N-pre JD open in P . In consequence inverse image of all N-regular open set implies N-pre JD open. For this reason, d is N-pre JD cont.





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Theorem 3.15: Let $(P, \tau_R(E))$ and $(Q, \tau_{R'}(F))$ be two N.T.S and let the mapping be $d: (P, \tau_R(E)) \rightarrow (Q, \tau_{R'}(F))$, then all N-precont. function is N-pre JD cont. function.

For, Let $d: (P, \tau_R(E)) \rightarrow (Q, \tau_{R'}(F))$ be N-pre cont. and L be N-pre open which is in Q . Then $d^{-1}(L)$ is N-pre open in P . As all N-pre o-set is N-pre JD-o, $d^{-1}(L)$ is N-pre JD-o in P . In consequence inverse image of all N-pre o-set implies N-pre JD-o. For this reason, d is N-pre JD cont.

Theorem 3.16: Let $(P, \tau_R(E))$ and $(Q, \tau_{R'}(F))$ be two N.T.S and let the mapping be $d: (P, \tau_R(E)) \rightarrow (Q, \tau_{R'}(F))$, then all N-pre* cont. function is N-pre JD cont. function.

For, Let $d: (P, \tau_R(E)) \rightarrow (Q, \tau_{R'}(F))$ be N-pre* cont. and L be N-pre* open which is in Q . Then $d^{-1}(L)$ is N-pre* open in P . As all N-o-s is N-pre JD open, $d^{-1}(L)$ is N-pre JD open in P . In consequence inverse image of all N-pre* open set implies N-pre JD open. For this reason, d is N-pre JD cont.

Theorem 3.17: Let $(P, \tau_R(E))$ and $(Q, \tau_{R'}(F))$ be two N.T.S and let the mapping be $d: (P, \tau_R(E)) \rightarrow (Q, \tau_{R'}(F))$, then all N- α cont. function is N-pre JD cont. function.

For, Let $d: (P, \tau_R(E)) \rightarrow (Q, \tau_{R'}(F))$ be N- α cont. and L be N- α open which is in Q . Then $d^{-1}(L)$ is N- α open in P . As all N- α open set is N-pre JD open, $d^{-1}(L)$ is N-pre JD open in P . In consequence inverse image of all N- α open set implies N-pre JD open. For this reason, d is N-pre JD cont.

Theorem 3.18: Let $(P, \tau_R(E))$ and $(Q, \tau_{R'}(F))$ be two N.T.S and let the mapping be $d: (P, \tau_R(E)) \rightarrow (Q, \tau_{R'}(F))$, then all N- α^* cont. function is N-pre JD cont. function.

For, Let $d: (P, \tau_R(E)) \rightarrow (Q, \tau_{R'}(F))$ be N- α^* cont. and L be N- α^* open which is in Q . Then $d^{-1}(L)$ is N- α^* open in P . As all N- α^* open set is N-pre JD open, $d^{-1}(L)$ is N-pre JD open in P . In consequence inverse image of all N- α^* open set implies N-pre JD open. For this reason, d is N-pre JD cont.

Theorem 3.19: Let $(P, \tau_R(E))$ and $(Q, \tau_{R'}(F))$ be two N.T.S and let the mapping be $d: (P, \tau_R(E)) \rightarrow (Q, \tau_{R'}(F))$, then all N- b cont. function is N-pre JD cont. function.

For, Let $d: (P, \tau_R(E)) \rightarrow (Q, \tau_{R'}(F))$ be Nano b cont. and L be N- b open which is in Q . Then $d^{-1}(L)$ is N- b open in P . As all N- b open set is N-pre JD open, $d^{-1}(L)$ is N-pre JD open in P . In consequence inverse image of all N- b open set implies N-pre JD open. For this reason, d is N-pre JD cont.

Theorem 3.20: Let $(P, \tau_R(E))$ and $(Q, \tau_{R'}(F))$ be two N.T.S and let the mapping be $d: (P, \tau_R(E)) \rightarrow (Q, \tau_{R'}(F))$, then all N- D cont. function is N-pre JD cont. function.

For, Let $d: (P, \tau_R(E)) \rightarrow (Q, \tau_{R'}(F))$ be N- D cont. and L be N- D open which is in Q . Then in P , $d^{-1}(L)$ is N- D -o. As all N- D o-set is N-pre JD-o, $d^{-1}(L)$ is N-pre JD-o in P . In consequence inverse image of all N- D open set implies N-pre JD open. For this reason, d is N-pre JD cont.

Theorem 3.21: Let $(P, \tau_R(E))$ and $(Q, \tau_{R'}(F))$ be two N.T.S and let the mapping be $d: (P, \tau_R(E)) \rightarrow (Q, \tau_{R'}(F))$, then all N-JD* cont. function is Nano pre JD cont. function.

For, Let $d: (P, \tau_R(E)) \rightarrow (Q, \tau_{R'}(F))$ be N-JD* cont. and L be N-JD* open which is in Q . Then $d^{-1}(L)$ is N-JD* open in P . As all N-JD* open set is N-pre JD open, $d^{-1}(L)$ is N-pre JD open in P . In consequence inverse image of all N-JD* open set implies N-pre JD open. For this reason, d is N-pre JD cont.

Theorem 3.22: Let $(P, \tau_R(E))$ and $(Q, \tau_{R'}(F))$ be two N.T.S and let the mapping be $d: (P, \tau_R(E)) \rightarrow (Q, \tau_{R'}(F))$, then all N-JD** cont. function is N-pre JD cont. function.

For, Let $d: (P, \tau_R(E)) \rightarrow (Q, \tau_{R'}(F))$ be N-JD** cont. and L be N-JD** open which is in Q . Then $d^{-1}(L)$ is N-JD** open in P . As all N-JD** open set implies N-pre JD open, $d^{-1}(L)$ is N-pre JD open in P . In consequence inverse image of all N-JD** open set is N-pre JD open. For this reason, d is N-pre JD cont.

Theorem 3.23: Let $(P, \tau_R(E))$ and $(Q, \tau_{R'}(F))$ be two N.T.S and let the mapping be $d: (P, \tau_R(E)) \rightarrow (Q, \tau_{R'}(F))$, then all N-semi* cont. function is Nano pre JD cont. function.





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For, Let $d: (P, \tau_R(E)) \rightarrow (Q, \tau_{R'}(F))$ be N-semi* cont. and L be N-semi* open which is in Q . Then $d^{-1}(L)$ is N-semi* open in P . As all N-semi* o-set is N-pre JD-o, $d^{-1}(L)$ is N-pre JD-o in P . In consequence inverse image of all N-semi* o-set implies N-pre JD-o. For this reason, d is N-pre JD cont.

Theorem 3.24: Let $(P, \tau_R(E))$ and $(Q, \tau_{R'}(F))$ be two N.T.S and let the mapping be $d: (P, \tau_R(E)) \rightarrow (Q, \tau_{R'}(F))$, then all N-semi cont. function is N-pre JD cont. function.

For, Let $d: (P, \tau_R(E)) \rightarrow (Q, \tau_{R'}(F))$ be N-semi cont. and L be N-semi open which is in Q . Then $d^{-1}(L)$ is N-semi open in P . As all N-semi open set is N-pre JD open, $d^{-1}(L)$ is N-pre JD open in P . In consequence inverse image of all N-semi open set implies N-pre JD open. For this reason, d is N-pre JD cont.

Theorem 3.25: Let $(P, \tau_R(E))$ and $(Q, \tau_{R'}(F))$ be two N.T.S and let the mapping be $d: (P, \tau_R(E)) \rightarrow (Q, \tau_{R'}(F))$, then every N- β cont. function is N-pre JD cont. function.

For, Let $d: (P, \tau_R(E)) \rightarrow (Q, \tau_{R'}(F))$ be N- β cont. and L be N- β open which is in Q . Then $d^{-1}(L)$ is N- β open in P . As all N- β open set is N-pre JD open, $d^{-1}(L)$ is N-pre JD open in P . In consequence inverse image of all N- β -o-set implies N-pre JD open. For this reason, d is N-pre JD cont.

Remark 3.26: The Converse of the theorems mentioned earlier may not turn out to be true.

For instance,

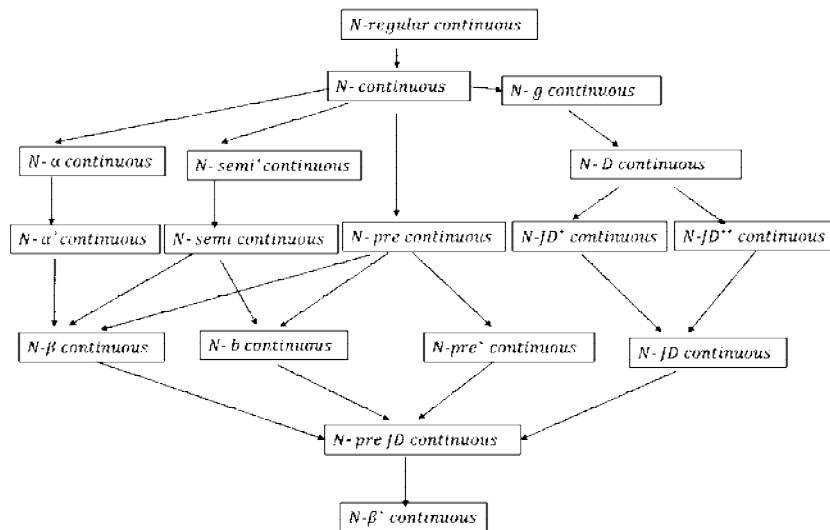
- i. Let $P = \{3,5,7\}$ and $P/R = \{\{3,5\}, \{7\}\}$ and $E = \{3,5\}$. Then the N.T $\tau_R(E) = \{P, \emptyset, \{3,5\}\}$. Here N-regular open = $\{P, \emptyset\}$. N-semi open, N-semi* open, N- α open = $\{P, \emptyset, \{3,5\}\}$. N-g open, N-D open, N-JD* open = $\{P, \emptyset, \{3\}, \{5\}, \{3,5\}\}$. N-pre JD open = $\{P, \emptyset, \{3\}, \{5\}, \{3,5\}, \{3,7\}, \{5,7\}\}$. Let $Q = \{4,6,8\}$ and $Q/R' = \{\{4\}, \{6,8\}\}$ and $F = \{8\}$. Then the N.T $\tau_{R'}(F) = \{Q, \emptyset, \{6,8\}\}$. Define a mapping $d: (P, \tau_R(E)) \rightarrow (Q, \tau_{R'}(F))$ as $d(3) = 4, d(5) = 6, d(7) = 8$. Then $d^{-1}(\{6,8\}) = \{5,7\}$. Here the inverse image of every open set in $\tau_{R'}(F)$ is Nano pre JD open in $(P, \tau_R(E))$ but not N-open, N-regular open, N-semi open, N-semi* open, N- α open, N-g open, N-D open, N-JD* open.
- ii. Let $P = \{1,5,3,7\}$ and $P/R = \{\{1\}, \{5\}, \{3,7\}\}$ and $E = \{1,3\}$. Then the N.T $\tau_R(E) = \{P, \emptyset, \{1\}, \{3,7\}, \{1,3,7\}\}$. Here N-pre open, N-pre* open, N- α * open, N-b open, N-JD** open = $\{P, \emptyset, \{1\}, \{3\}, \{7\}, \{1,3\}, \{1,7\}, \{3,7\}, \{1,5,3\}, \{1,5,7\}, \{1,3,7\}\}$. N-JD open = $\{P, \emptyset, \{1\}, \{3\}, \{7\}, \{1,5\}, \{1,3\}, \{1,7\}, \{3,7\}, \{1,5,3\}, \{1,5,7\}, \{1,3,7\}, \{5,3,7\}\}$. N-pre JD open = $\{P, \emptyset, \{1\}, \{3\}, \{7\}, \{1,5\}, \{1,3\}, \{1,7\}, \{5,3\}, \{5,7\}, \{3,7\}, \{1,5,3\}, \{1,5,7\}, \{1,3,7\}, \{5,3,7\}\}$. Let $Q = \{8,4,2,6\}$ and $Q/R' = \{\{8\}, \{6\}, \{4,2\}\}$ and $F = \{8,6\}$. Then the N.T $\tau_{R'}(F) = \{Q, \emptyset, \{8,6\}\}$. Define a mapping $d: (P, \tau_R(E)) \rightarrow (Q, \tau_{R'}(F))$ as $d(1) = 4, d(5) = 8, d(3) = 6, d(7) = 2$. Then $d^{-1}(\{8,6\}) = \{5,3\}$. Here the inverse image of all open set in $\tau_{R'}(F)$ is N-pre JD open in $(P, \tau_R(E))$ but not N-pre open, N-pre* open, N- α * open, N-b open, N-JD open, N-JD** open.
- iii. Let $P = \{4,8,3,6\}$ and $P/R = \{\{4\}, \{6\}, \{8,3\}\}$ and $E = \{4,6\}$. Then the N.T $\tau_R(E) = \{P, \emptyset, \{4,6\}\}$. Here N- β open = $\{P, \emptyset, \{4\}, \{3\}, \{6\}, \{4,3\}, \{4,6\}, \{3,6\}, \{4,8,3\}, \{4,8,6\}, \{4,3,6\}\}$. N-pre JD open = $\{P, \emptyset, \{4\}, \{6\}, \{4,8\}, \{4,3\}, \{4,6\}, \{8,3\}, \{3,6\}, \{4,8,3\}, \{4,8,6\}, \{4,3,6\}, \{8,3,6\}\}$. Let $Q = \{1,5,7,9\}$ and $Q/R' = \{\{1\}, \{5\}, \{7\}, \{9\}\}$ and $F = \{1,5\}$. Then the N.T $\tau_{R'}(F) = \{Q, \emptyset, \{1,5\}\}$. Define a mapping $d: (P, \tau_R(E)) \rightarrow (Q, \tau_{R'}(F))$ as $d(4) = 7, d(8) = 1, d(3) = 5, d(6) = 9$. Then $d^{-1}(\{1,5\}) = \{8,3\}$. Here the inverse image of all open set in $\tau_{R'}(F)$ is N-pre JD open in $(P, \tau_R(E))$ but not N- β open.

Diagram 1: The relations discussed above are shown in the below diagram the converse of any considered set need not necessarily be true.





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Theorem 3.27: Let $(P, \tau_R(E))$ and $(Q, \tau_{R'}(F))$ be two N.T.S and let the mapping be $d: (P, \tau_R(E)) \rightarrow (Q, \tau_{R'}(F))$, then all $N-\beta^*$ cont. function is $N-pre JD$ cont. function and conversely.

For, Let $d: (P, \tau_R(E)) \rightarrow (Q, \tau_{R'}(F))$ be $N-\beta^*$ cont. and L be $N-\beta^*$ open in Q . Then $d^{-1}(L)$ is $N-\beta^*$ open in P . As all $N-\beta^*$ open set is $N-pre JD$ open, $d^{-1}(L)$ is $N-pre JD$ open in P . In consequence inverse image of all $N-\beta^*$ open set is $N-pre JD$ open. For this reason, d is $N-pre JD$ cont.

Conversely, let $d: (P, \tau_R(E)) \rightarrow (Q, \tau_{R'}(F))$ be $N-pre JD$ cont. and L be $N-pre JD$ open in Q . Then $d^{-1}(L)$ is $N-pre JD$ open in P . As all $N-pre JD$ open set is $N-\beta^*$ open, $d^{-1}(L)$ is $N-\beta^*$ open in P . In consequence inverse image of all $N-pre JD$ open set is $N-\beta^*$ open. For this reason, d is $N-\beta^*$ cont.

N-PRE JD IRRESOLUTE FUNCTIONS IN N.T.S

Definition 4.1: A function $d: (P, \tau_R(E)) \rightarrow (Q, \tau_{R'}(F))$ is defined a $N-pre JD$ irresolute if inverse image is $N-pre JD$ open set in $(P, \tau_R(E))$ for all $N-pre JD$ open set in $(Q, \tau_{R'}(F))$.

Theorem 4.2: A map $d: (P, \tau_R(E)) \rightarrow (Q, \tau_{R'}(F))$ is $N-pre JD$ irresolute if, and only if the inverse image of all $N-pre JD$ -c-s in $\tau_{R'}(F)$ is $N-pre JD$ -c in $\tau_R(E)$.

For, Assume that d is $N-pre JD$ irresolute map and let L be any $N-pre JD$ closed set in Q . Then $Q \setminus L$ is $N-pre JD$ -o in Q . As d is $N-pre JD$ irresolute, $d^{-1}(Q \setminus L)$ is $N-pre JD$ -o in P . But $d^{-1}(Q \setminus L) = P \setminus d^{-1}(L)$ and so $d^{-1}(L)$ is $N-pre JD$ -c in P . Hence the inverse image of all $N-pre JD$ -c-s in Q is $N-pre JD$ -c in P . Conversely, assume that the inverse image of all $N-pre JD$ closed set in Q is $N-pre JD$ -c-s in P . Let L be any $N-pre JD$ -o-s in Q . Then $Q \setminus L$ is $N-pre JD$ closed set in Q . By assumption, $d^{-1}(Q \setminus L)$ is $N-pre JD$ -c-s in P . But $d^{-1}(Q \setminus L) = P \setminus d^{-1}(L)$ and so $d^{-1}(L)$ is $N-pre JD$ -o-s in P . For this reason, d is $N-pre JD$ irresolute.

Theorem 4.3: Every $N-pre JD$ irresolute map is $N-pre JD$ cont.

For, Let $\rho: (P, \tau_R(E)) \rightarrow (Q, \tau_{R'}(F))$ be a $N-JD$ irresolute map. Let L be N -o-s in Q . Then L is $N-pre JD$ open set in Q . As ρ is $N-pre JD$ irresolute map, $\rho^{-1}(L)$ is $N-pre JD$ open in P . For this reason, ρ is $N-pre JD$ cont.

Remark 4.4: The Converse of the theorems mentioned earlier may not turn out to be true.

For instance, Let $P = \{5,6,7,8\}$ and $P/R = \{\{5\}, \{6\}, \{7,8\}\}$ and $E = \{5,7\}$. Then the N.T $\tau_R(E) = \{P, \emptyset, \{5\}, \{7,8\}, \{5,7,8\}\}$. Here $N-pre JD$ -o = $\{P, \emptyset, \{5\}, \{7\}, \{8\}, \{5,6\}, \{5,7\}, \{5,8\}, \{6,7\}, \{6,8\}, \{7,8\}, \{5,6,7\}, \{5,6,8\}, \{5,7,8\}, \{6,7,8\}\}$. Let $Q = \{1,2,3,4\}$ and





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$Q / R' = \{\{1\}, \{2\}, \{3\}, \{4\}\}$ and $F = \{1,2\}$. Then the N.T $\tau_{R'}(F) = \{Q, \emptyset, \{1,2\}\}$. Here N-pre JD-o = $\{Q, \emptyset, \{1\}, \{2\}, \{3\}, \{4\}, \{1,2\}, \{1,3\}, \{1,4\}, \{2,3\}, \{2,4\}, \{3,4\}, \{1,2,3\}, \{1,2,4\}, \{1,3,4\}, \{2,3,4\}\}$. Define a mapping $\rho : (P, \tau_R(E)) \rightarrow (Q, \tau_{R'}(F))$ as $\rho(5) = 1, \rho(6) = 2, \rho(7) = 3, \rho(8) = 4$. Then $\rho^{-1}(\{1,2\}) = \{5,6\}$. Here the inverse image of all o-set in $\tau_{R'}(F)$ is N-pre JD-o in $(P, \tau_R(E))$. For this reason, ρ is N-pre JD cont. but not N-pre JD irresolute since the inverse image of N-pre JD open in $(Q, \tau_{R'}(F))$ i.e. $\rho^{-1}(\{2\}) = 6$ is not N-pre JD-o in $(P, \tau_R(E))$

Theorem 4.5: Let $(P, \tau_R(E)), (Q, \tau_{R'}(F)), (S, \tau_{R''}(G))$ be any N.T.S. For any N-pre JD irresolute map $\mu: (P, \tau_R(E)) \rightarrow (Q, \tau_{R'}(F))$ and $\delta: (Q, \tau_{R'}(F)) \rightarrow (S, \tau_{R''}(G))$ be any two N-pre JD cont. map. Then their composition $\delta \circ \mu: (P, \tau_R(E)) \rightarrow (S, \tau_{R''}(G))$ is N-pre JD cont.

For, Let L be any N-o-s in S . As δ is N-pre JD cont., $\delta^{-1}(L)$ is N-pre JD-o in Q and μ is N-pre JD irresolute, $\mu^{-1}(\delta^{-1}(L))$ is N-pre JD-o in P . But $\mu^{-1}(\delta^{-1}(L)) = (\delta \circ \mu)^{-1}(L)$. For this reason, $\delta \circ \mu: (P, \tau_R(E)) \rightarrow (S, \tau_{R''}(G))$ is N-pre JD cont.

Theorem 4.6: Let $\mu: (P, \tau_R(E)) \rightarrow (Q, \tau_{R'}(F))$ and $\delta: (Q, \tau_{R'}(F)) \rightarrow (S, \tau_{R''}(G))$ be any two functions, then

i) $\delta \circ \mu: (P, \tau_R(E)) \rightarrow (S, \tau_{R''}(G))$ is N-pre JD cont. if δ is N-cont. and μ is N-pre JD cont.

ii) $\delta \circ \mu: (P, \tau_R(E)) \rightarrow (S, \tau_{R''}(G))$ is N-pre JD irresolute if both μ and δ is N-pre JD irresolute.

For, (i) Let L be a N-o-s in $(S, \tau_{R''}(G))$. Since μ is N-cont., we get $\delta^{-1}(L)$ to be N-o in $(Q, \tau_{R'}(F))$. Here μ is N-pre JD cont., $\mu^{-1}(\delta^{-1}(L)) = (\delta \circ \mu)^{-1}(L)$ is N-pre JD-o in $(P, \tau_R(E))$. Hence $\delta \circ \mu$ is N-pre JD cont.

(ii) Let L be a N-pre JD open set in $(S, \tau_{R''}(G))$. As δ is N-pre JD irresolute, we get $\delta^{-1}(L)$ to be N-pre JD open in $(Q, \tau_{R'}(F))$. Also μ is N-pre JD irresolute, this implies, $\mu^{-1}(\delta^{-1}(L)) = (\delta \circ \mu)^{-1}(L)$ is N-pre JD-o in $(P, \tau_R(E))$. For this reason $\delta \circ \mu$ is N-pre JD irresolute.

REFERENCES

1. Anuf Sarumathi. J, Stella Arputha Mary.V.L, Nano Pre JD open sets in Nano Topological Spaces, National Conference on Mathematical Modelling and Computation (NCMMC 2024) Proceedings (Communicated).
2. Mary D A, Arokia Rani A, On Semi pre open sets in Nano Topological Spaces, Math, Sci, Int. Journal 3(2014), 771-773.
3. Thivagar M.L, Richard C (2013) On Nano forms of Weakly open sets, Int Journal of Mathematics and Statistics Invention, 1, 31-37.
4. Thivagar M.L, Richard C(2013), On Nano continuity, Mathematical Theory and Modeling ISSN 2224-5804(Paper), ISSN 2225-0522(online) Vol.3 No. 7, 2013.
5. Thivagar M.L, Richard C, Note on Nano Topological Spaces.





Potential Drug Target from Breast Milk *Lactobacillus* against Vaginal Pathogens

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ABSTRACT

The term “Probiotics” refers to the micro-organisms that confers health benefits to hosts when administered in adequate amounts. In this work, *Lactobacillus* was isolated from breast milk of a 26 yr old women and was treated against vaginal pathogens by varying in different concentration (50µl, 40µl and 30µl). Identification of *Lactobacillus* was carried out by motility, gram staining and biochemical test. The antibacterial effects of the *Lactobacillus* against vaginal pathogens were carried out by disc Agar diffusion method and Antibiotic sensitivity test was also analysed for the pathogens. The antimicrobial activity of the sample revealed that the *Lactobacillus* isolated from breast milk showed significant effectively against vaginal pathogens especially higher for *Klebsiella pneumoniae*. GC-MS was carried out to identify bioactive compounds, followed by the identification of novel bioactive compounds in the corresponding fraction. The main aim is to assess the probiotic nature of *Lactobacillus* in preventing cervical pathogens by studying the effectiveness of antimicrobial activity against vaginal pathogens by identifying the effective compounds by GC-MS and they may widened up the panorama in research and may act as a promising natural human source based drug in medical field without taking any chemical drugs which cause side effects.

Keywords: Probiotic, Vaginal pathogens, *Lactobacillus*, LMW compounds, GC-MS, Antimicrobial compounds





INTRODUCTION

A literal probiotic should preferably be of human origin, safe, and free of vectors that are able to transfer resistance to antibiotics and of pathogenicity or toxicity factors. In addition, a probiotic should have great range to survive under intestinal conditions (acidic pH, enzymes, biliary salts, etc.). Moreover, a probiotic should exhibit antagonism against pathogens and stimulation of the immune system and, ultimately, must have demonstrable beneficial effects on the host [1-3]. Finally, maintenance of the activity, viability, and growth potency of the probiotic upon technologic treatment should be demonstrated [4-5]. The effects of probiotics on host health have been reported in many articles, reviews, and systematic reviews [6-7]. These studies have documented the role of probiotics in the prevention of health problems, including digestive disorders such as diarrhea caused by infections [4], antibiotic-associated diarrhea [8], irritable bowel syndrome (IBS) [9], *Clostridium difficile*-associated diarrhea in adults and children [10], inflammatory bowel disease (IBD), only in ulcerative colitis [11], and allergic disorders such as atopic dermatitis (eczema) [12] and allergic rhinitis [13]. Probiotics are made of good live bacteria and/or yeasts that naturally live in our body. Though there are many types of bacteria that can be considered to be probiotics, there are two specific types of bacteria that are common probiotics found in stores. These include *Lactobacillus* and *Bifidobacterium* [14].

Antibiotic treatments can upset the gut microbiome and its normal balance of “good” and “bad” bacteria, leading to diarrhoea. Probiotics taken before, during, and after antibiotic treatment can reduce the chances of diarrhoea, according to several studies. But, researchers have had mixed results regarding the benefits of probiotics in preventing traveller’s diarrhoea [15]. Many other claims are made for probiotics—that they lower cholesterol, alleviate allergic skin conditions (like eczema), treat ulcers and urinary tract infections, improve vaginal health, reduce the risk of colon cancer, ease anxiety and ward off traveler’s diarrhea. Good evidence to support these claims is lacking. Research on probiotics for weight loss has yielded conflicting results, and even studies with positive results have mostly found very small benefits, as was seen in an analysis of 15 clinical trials in Obesity Reviews in 2018 [16]. There is remarkable prevalence of RTIs in pregnant females (68%). These infections are known to produce inevitable conclusion in pregnancy. This alarms for a needful action in this group of females because of the complications associated with these infections in pregnancy [17]. Increase number of cases were seen in third trimester of gestation. These infections are more seen in third trimester of pregnancy because as pregnancy advances, various hormonal changes take place and thus occurrence of endogenous RTIs increases.16 Overall, candidiasis was the most prevalent infection seen in pregnant women (36.36%) followed by BV (25%), TV (4.5%).[18]

To comprehend the emerging needs of supplements, probiotics used in health food industry moreover many investigations are focusing on probiotics potential LAB isolation from different resources of fermented milk, foods, Taiwanese pickled cabbage and faeces of breast-fed infants [19-21]. In addition, it also contains bioactive compounds responsible for a wide range of beneficial effects such as the promotion of immune system maturation and the protection against infections. Among these bioactive agents, probiotic bacteria have been recently isolated from human milk. Among these bioactive agents, probiotic bacteria have been recently isolated from human milk [22]. Several studies have reported that human breast milk contains complex microbial community. This community impacts the shape of the infant gut microbiota and consequently impacts host health. *Lactobacillus* is an important probiotic and has many applications in the functional food industry [23]. The role of *Lactobacillus* species in the female urogenital tract as a barrier to infection is of considerable interest. These organisms are believed to contribute to the control of vaginal microbiota by competing with other microorganisms for adherence to epithelial cells and by producing antimicrobial compounds.[24] The maternal gut is the vital source of commensal bacteria in the infant gut during the lactation stage, where breast milk acts as an intermediary for the transfer of potential probiotic bacteria consortia, including *Lactobacillus*. [25] The isolation of probiotic bacteria with beneficial effects for the host provides scientific support for the supplementation of infant formula with these bacteria, in order to advance the pursuit of the main goal of formula: to mimic breast milk and its functional effects as closely as possible.





MATERIALS AND METHODS

Sample collection

Breast milk was collected from a breast feeding mother of 26 yr. old healthy women. The sample was maintained in a sterile container and pure culture was done. Bacterial colonies were stored in 0.8% MRS agar overlaid with 50% glycerol at -20°C.

Isolation of *Lactobacillus* species from Breast milk

Lactobacillus sp. was isolated from breast milk and the sample was taken in sterilized flask, and experiment was carried out. The milk was serially diluted to get different dilutions. From that dilution the sample was spreaded on MRS medium and incubated at 37°C which is optimum temperature for *Lactobacillus* growth. Incubation is carried out for 24 hours. After the period of incubation, the isolated colonies were grown and colony characterization was done for this colonies which are found to be *Lactobacillus* species. The isolated colony formed on the MRS agar plates was identified using gram staining and biochemical test. The identification was performed according to Bergey's manual of determinative of bacteriology.

Morphological examination of culture

Cultural and Morphological examination was carried out by using Gram's staining method described by Hans Christian Gram (1884).

Identification of the pure culture

Pure culture isolated from MRS agar slant was identified with the help of biochemical tests like motility test, catalase test, urease test, TSI test, citrate utilization test, oxidase test, MR-VP, indole and sugar fermentation test.

Motility test

Soft agar test was used for the testing if the bacteria were motile or non-motile through stab inoculation.

Bacterial strain and culture conditions

One-gram negative and two gram positive bacteria were used for antibacterial assay respectively. *Klebsiella pneumonia*, *Staphylococcus aureus* and *Enterococcus faecalis* were purchased from Magnum Diagnostic Centre, Trichy. These gram positive and gram negative test organisms were maintained in brain heart infusion agar butt slants in screw capped tubes and kept at 4°C.

Biochemical characterization of the isolated bacterial strain

Identification of the isolated bacteria as *Lactobacillus* sp. and vaginal pathogens were performed according to their morphological, cultural, physiological and biochemical characteristics by the procedures as described in bergey's manual of systematic bacteriology. The test carried out were gram staining, motility test, production of catalase, indole, methyl red, voges-proskauer, citrate utilization, urease, TSI, oxidase, indole and carbohydrate fermentative test.

Antibacterial/ Antimicrobial activity testing

Microorganism

Staphylococcus aureus, *Enterococcus faecalis*, *Klebsiella pneumoniae* were purchased from Magnum Diagnostic Centre, Trichy.

Antimicrobial activity screening using *Lactobacillus* strain:

The Mueller Hinton agar (MHA) medium was used for agar well diffusion approach to examine antibacterial test. The Mueller Hinton agar (MHA) medium was poured in petri plate and allowed to solidify. Bacterial suspension



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(*Klebsiella pneumoniae*, *Staphylococcus aureus*, *Enterococcus faecalis*) was enriched in saline for 4 hours. 100µl of bacterial culture was spread aseptically over the Mueller Hinton agar plates using a sterile cotton swab. *Lactobacillus* species isolated from three different sample breast milk was centrifuged at 5000 rpm for 15 minutes and supernatant was taken without disturbing the pellet. Using sterile 100µl tip (micropipette tips) agar gel was punctured to create well. Supernatant of three different sample were loaded into those wells and saline water was used as control. All plates were incubated at 37°C for 24 hours. The antimicrobial properties were determined by measuring of the zone of inhibition (diameter) (Subramanyam Dasari *et al.*, 2014).

Antibiotic sensitivity test

Three bacterial colonies (*Klebsiella pneumoniae*, *Staphylococcus aureus* and *Enterococcus faecalis*) were touched by cold heat sterilized nichrome wire inoculation loop and the same was inoculated into sterile 2µl of normal saline water. The saline water was incubated at 37°C for 4 hours to get light to moderate turbidity, which were yield young colonies. The freshly grown organisms were uniformly inoculated aseptically into Mueller Hinton agar by using sterile swab. The required antibiotic disc Ampicillin, Ofloxacin, Gentamycin, Amphotericin B, Vancomycin, Nitrofurantoin were placed over the lawn culture by using sterile forceps. The petriplate was incubated at 37°C for 18-24 hours. After the completion of this period the inhibited zones by the antibiotics were measured in a well light sourced safety hood. (Lias *et al.*, 2009).

Gas chromatography-mass spectroscopy (GC-MS)

GC-MS analysis of extracellular compounds were performed as previously described. Briefly, the compounds were extracted with methanol and chloroform. 1µl of both the methanol and chloroform extracts was separated on a nonpolar HP-5MS capillary column (30 m × 0.18 mm) in a Agilent GC fitted to an Agilent MS detector. The injector temperature was 250°C and the oven temperature was programmed at an initial temperature of 50° C for 1 min, rising at 25°C per minute to 160° C and maintained at that temperature for 1 min. The temperature was subsequently increased by 10° C per min to 230° C and maintained at that temperature for a further 4.6 min. The carrier gas helium was kept at a constant pressure of 5 kPa. The GC was directly interfaced with an Agilent mass spectrometer with an interface temperature of 250°C. Sample ionization was done by 70 eV electron impact and was analysed in positive mode. Structural determination was by comparison of mass spectral patterns to NIST data bases.

RESULTS AND DISCUSSION**Isolation of pure colonies from Breast Milk sample**

In the present investigation, *Lactobacillus* was isolated from breast milk and named as BMSD.

Sub culturing different colonies (subsequent days)

Subculture the different colonies of sample (BMSD) for subsequent hours as following 34 hours, 48 hours, 72 hours, 96 hours, 120 hours. On MRS agar plates, pure white colonies were observed and this was identified as *Lactobacillus* sp. (Fig 1)

Gram's staining

Gram's staining was performed for all colonies for the study of different morphologies. Luxuriantly grown bright white colonies from MRS agar were selected for gram's staining. When specimen was observed under 100X (oil immersion) gram positive purple colour rod shaped bacilli were observed. (Fig 2)

Preparation of stock culture

In 80µl of MRS broth, culture of *Lactobacillus* sp. was inoculated and incubated the standing culture at 37°C in an incubator. This obtained broth is the stock culture which is used for future studies.



**Sandhiya and Jeyabharathi****Biochemical characterization**

The biochemical characterization of the sample BMSD was as follows: (Table:1)

Antimicrobial screening using *Lactobacillus* sp

The zone of inhibition was measured for both antimicrobial and antibiotic sensitivity test against the pathogenic organisms:

Antibiotic sensitivity test

The zone of inhibition was measured for antibiotics against the pathogenic organisms which were shown in (Fig 3) The antibiotic sensitive test of antibiotics was investigated against pathogenic organisms *Klebsiella pneumoniae*, *Staphylococcus aureus* and *Enterococcus faecalis*. For *Klebsiella pneumoniae*, ofloxacin showed maximum zone of inhibition than Amphotericin B, followed by *Enterococcus faecalis*, Nitofurantoin showed maximum zone of inhibition than vancomycin and for *Staphylococcus aureus*, gentamycin showed maximum zone of inhibition than vancomycin.

Antimicrobial screening

The zone of inhibition was measured for BMSD against the pathogenic organisms were shown in (Fig 4) The antimicrobial activity of BMSD was investigated against pathogenic organisms *Klebsiella pneumoniae*, *Staphylococcus aureus* and *Enterococcus faecalis*. The highest antimicrobial activity was observed for BMSD against *Klebsiella pneumoniae* (38mm), *Enterococcus faecalis* (34mm), *Staphylococcus aureus* (35mm) in 50 µl concentration respectively. The antimicrobial activity of BMSD-1 was investigated against pathogenic organisms *Klebsiella pneumoniae*, *Staphylococcus aureus* and *Enterococcus faecalis* in different concentrations. The highest antimicrobial activity was observed against *Klebsiella pneumoniae* (38mm in 50 µl conc.), (22mm in 40µl conc.), and (20mm in 30µl conc.) respectively, followed by *Enterococcus faecalis* (34mm in 50 µl conc.), (22mm in 40µl conc.), and *Staphylococcus aureus* (35mm in 50 µl conc.), (20mm in 40µl conc.), and (16mm in 30µl conc.) (Fig 5)

GC-MS Analysis of the extracellular components

The main component of extracellular compounds found from *Lactobacillus* was found to be lactic acid and the graph was drawn in Fig 6(a) from the observed values illustrated in the table 5. The molecular structure of lactic acid in fig 6 (b) shows gives the clarity and evidence for the work.

CONCLUSION

A study was initiated to know the antimicrobial activity of *Lactobacillus* isolated from breast milk against vaginal pathogens (*Klebsiella pneumoniae*, *Staphylococcus aureus* and *Enterococcus faecalis*). In present investigation, *Lactobacillus* were isolated from breast milk sample from a healthy mother and was identified by grams staining, biochemical and motility test. The *Lactobacillus* was tested against vaginal pathogens for its antimicrobial screening in three different concentrations (30µl, 40µl and 50µl). Antibiotic sensitivity test for the vaginal pathogens were tested by using various antibiotic disc, by this test the sensitivity and resistivity to different antibiotics of vaginal pathogens were examined. In this work, *Lactobacillus* isolated from breast milk of a healthy mother showed maximum zone of inhibition in all three concentration against *Klebsiella pneumoniae* (38mm in 50 µl conc.), (22mm in 40µl conc.), and (20mm in 30µl conc.) respectively, followed by *Enterococcus faecalis* (34mm in 50 µl conc.), (22mm in 40µl conc.), and *Staphylococcus aureus* (35mm in 50 µl conc.), (20mm in 40µl conc.), and (16mm in 30µl conc.) The bioactive compounds present in *Lactobacillus* were determined by GC-MS method and molecular docking of these compound will be done in further studies. Hence, *Lactobacillus* a probiotic isolated from breast milk showed great effect against vaginal infection and these steps toward establishing “good science” may result in the approval of health claims in the near future.





REFERENCES

1. AO/WHO (2001) Evaluation of Health and Nutritional Properties of Probiotics in Food Including Powder Milk with Live Acid Bacteria. Report of a Joint FAO/WHO Expert Consultation, Córdoba, Argentina. http://www.who.int/foodsafety/publications/fs_management/en/probiotics.pdf?ua=1
2. Henrik Andersson, Nils-Georg Asp, Åke Bruce, Stefan Roos, Torkel Wadström, Health effects of probiotics and prebiotics A literature review on human studies, *Näringsforskning*, 45:1, (2001) 58-75, DOI: 10.3402/fnr.v45i0.1790
3. Aceti, A., Gori, D., Barone, G. et al. Probiotics for prevention of necrotizing enterocolitis in preterm infants: systematic review and meta-analysis. *Ital J Pediatr* 41, 89 (2015). <https://doi.org/10.1186/s13052-015-0199-2>
4. Plaza-Díaz J, Ruiz-Ojeda FJ, Gil-Campos M, Gil A. Immune-mediated mechanisms of action of probiotics and synbiotics in treating pediatric intestinal diseases. *Nutrients* 10 1:42(2018) doi: 10.3390/nu10010042.
5. Fontana, L., Bermudez-Brito, M., Plaza-Diaz, J., Muñoz-Quezada, S. & Gil, A. Sources, isolation, characterisation and evaluation of probiotics. *Br. J. Nutr.* 109 (2013) S35–S50 doi: 10.1017/S0007114512004011
6. Naseri A, Seyedi-Sahebari S, Mahmoodpoor A, Sanaie S. Probiotics in Critically Ill Patients: An Umbrella Review. *Indian J Crit Care Med.* 26(3) 2022 339-360. doi: 10.5005/jp-journals-10071-24129..
7. Martinelli M, Banderali G, Bobbio M, Civardi E, Chiara A, D'Elisio S, Lo Vecchio A, Olivero M, Probiotics' efficacy in paediatric diseases: which is the evidence? A critical review on behalf of the Italian Society of Pediatrics. *Ital J Pediatr.* 46(1): 2020 104. doi: 10.1186/s13052-020-00862-z.
8. Cremonini F, Videlock EJ. Probiotics are associated with a decreased risk of antibiotic-associated diarrhoea. *Evid Based Med.* 18(2): 2013 71-2. doi: 10.1136/eb-2012-100863.
9. Quartero AO, Meineche-Schmidt V, Muris J, Rubin G, de Wit N. Bulking agents, antispasmodic and antidepressant medication for the treatment of irritable bowel syndrome. *Cochrane Database Syst Rev.* 18;(2):2005 doi: 10.1002/14651858.CD003460.
10. Goldenberg JZ, Yap C, Lytvyn L, Lo CK, Beardsley J, Mertz D, Johnston BC. Probiotics for the prevention of Clostridium difficile-associated diarrhea in adults and children. *Cochrane Database Syst Rev* 12(12) 2017 doi: 10.1002/14651858.CD006095.pub4.
11. Ghouri YA, Richards DM, Rahimi EF, Krill JT, Jelinek KA, DuPont AW. Systematic review of randomized controlled trials of probiotics, prebiotics, and synbiotics in inflammatory bowel disease. *Clin Exp Gastroenterol.* 7 2014 473-87. doi: 10.2147/CEG.S27530.
12. Anania C, Brindisi G, Martinelli I, Bonucci E, D'Orsi M, Ialongo S, Nyffenegger A, Raso T, Spatuzzo M, De Castro G, Zicari AM, Carraro C, Piccioni MG, Olivero F. Probiotics Function in Preventing Atopic Dermatitis in Children. *Int J Mol Sci.* 23(10): 2022 5409. doi: 10.3390/ijms23105409..
13. Matsuoka T, Shamji MH, Durham SR. Allergen immunotherapy and tolerance. *Allergol Int.* 62(4) 2013 03-13. doi: 10.2332/allergolint.13-RAI-0650
14. Su GL, Ko CW, Bercik P, Falck-Ytter Y, Sultan S, Weizman AV, Morgan RL. AGA Clinical Practice Guidelines on the Role of Probiotics in the Management of Gastrointestinal Disorders. *Gastroenterology.* 159(2) 2020 697-705. doi: 10.1053/j.gastro.2020.05.059.
15. Guo Q, Goldenberg JZ, Humphrey C, El Dib R, Johnston BC. Probiotics for the prevention of pediatric antibiotic-associated diarrhea. *Cochrane Database Syst Rev.* 2019 4(4): 2019 CD004827. doi: 10.1002/14651858.CD004827.pub5.
16. Nazir Y, Hussain SA, Abdul Hamid A, Song Y. Probiotics and Their Potential Preventive and Therapeutic Role for Cancer, High Serum Cholesterol, and Allergic and HIV Diseases. *Biomed Res Int.* Aug 29;2018:3428437. doi: 10.1155/2018/3428437.
17. Amiri M, Lavasani Z, Norouzirad R, Najibpour R, Mohamadpour M, Nikpoor AR, Raeisi M, Zare Marzouni H. Prevalence of Urinary Tract Infection Among Pregnant Women and its Complications in Their Newborns During the Birth in the Hospitals of Dezful City, Iran, 2012 - 2013. *Iran Red Crescent Med J.* 17(8): 2015 e26946. doi: 10.5812/ircmj.26946..





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18. Soong D, Einarson A. Vaginal yeast infections during pregnancy. *Can Fam Physician*. Mar; 55 (3): 2009 255-6.
19. Chang S, Tsai C, Wee C, Yan T Isolation and functional study of potentially probiotic Lactobacilli from Taiwan traditional paocai. *Afri J. Micro.Resr*. 7: 683-691.
20. Kaboosi H Antibacterial effects of probiotics isolated from yoghurts against some common bacterial pathogens. *Afri J. Micro.Resr*. 5: 2011 4363-4367.
21. Wang CY, Lin PR, Ng CC, Shyu YT (2010) Probiotic properties of strains isolated from the feces of breast-fed infants and Taiwanese pickled cabbage. *Elsevier Anaerobe* 16: 578-585.
22. Federico Lara-Villoslada¹, Mo'nica Olivares¹, Saleta Sierra¹, Juan Miguel Rodr'iguez², Julio Boza¹ and Jordi Xaus¹ Beneficial effects of probiotic bacteria isolated from breast milk *Brit J. Nutri* 98(1), 2007 S96–S100 doi: 10.1017/S0007114507832
23. Jiang M, Zhang F, Wan C, Xiong Y, Shah NP, Wei H, Tao X. Evaluation of probiotic properties of *Lactobacillus plantarum* WLPL04 isolated from human breast milk. *J Dairy Sci*. 99(3): 2016 1736-1746. doi: 10.3168/jds.2015-10434
24. McGroarty JA. Probiotic use of lactobacilli in the human female urogenital tract. *FEMS Immunol Med Microbiol*. 6(4): 1993 251-64. doi: 10.1111/j.1574-695X.1993.tb00337.x.
25. Jost T, Lacroix C, Braegger C, Chassard C. Impact of human milk bacteria and oligosaccharides on neonatal gut microbiota establishment and gut health. *Nutr Rev*. 73(7): 2015 426-37. doi: 10.1093/nutrit/nuu016.

Table:1 Biochemical characterization of BMSD

BIOCHEMICAL TEST	SAMPLE
	BMSD
Triple sugar iron agar	+
Urease test	-
Citrate utilization test	-
Catalase test	-
Oxidase test	-
Indole test	-
Methyl red test	-
Voges Prauskauer test	-
Sucrose	+
Glucose	+
Lactose	+

Table 2 : Prediction of Target for Lactic Acid: Probability scores for lactic acid - higher probability with indicated protein class is assumed as bioactive and to have this protein as target.

Target	Common name	Uniprot ID	ChEMBL ID	Target Class	Probability*
Tyrosine-protein kinase LCK	LCK	P06239	CHEMBL258	Kinase	0
Tyrosine-protein kinase FYN	FYN	P06241	CHEMBL1841	Kinase	0
Matrix metalloproteinase 9	MMP9	P14780	CHEMBL321	Protease	0
Matrix metalloproteinase 2	MMP2	P08253	CHEMBL333	Protease	0
HMG-CoA reductase	HMGCR	P04035	CHEMBL402	Oxidoreductase	0
Histone deacetylase 3	HDAC3	O15379	CHEMBL1829	Eraser	0
Estrogen receptor beta	ESR2	Q92731	CHEMBL242	Nuclear receptor	0
Fgl nine homolog 1	FGFN1	Q9G7T9	CHEMBL5697	Oxidoreductase	0
Aldose reductase	AKR1B1	P15121	CHEMBL1900	Enzyme	0.085
Adenylosuccinate synthetase 2	ADSS	P30520	CHEMBL4875	Enzyme	0
DNA Adenine Methylase	DAM	P0AEE9	CHEMBL1075075	Enzyme	0.11





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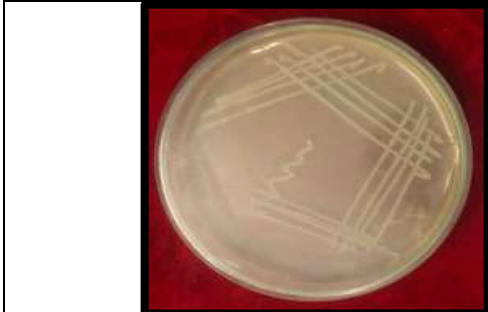


Fig 1 : Pure culture of BMSD

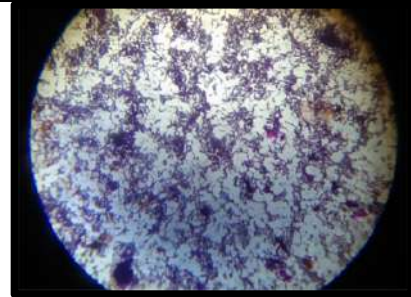


Fig 2 : Gram staining of BMSD

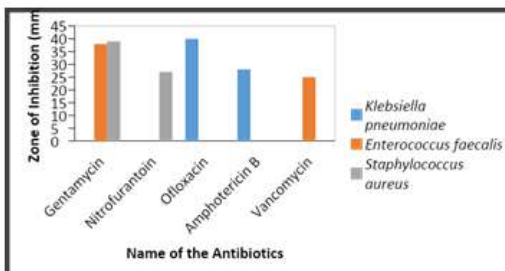


Fig 3 : Antibiotic sensitivity Test

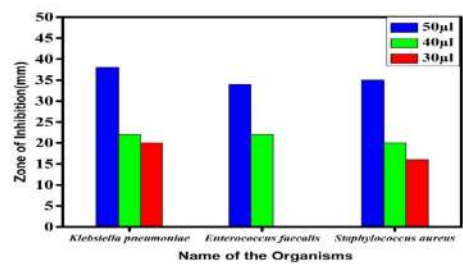


Fig 4. Antibacterial activity of BMSD



Fig 5: Maximum zone of inhibition shown by BMSD-1 against 1. *Klebsiella pneumoniae*, 2. *Enterococcus faecalis*, 3. *Staphylococcus aureus*

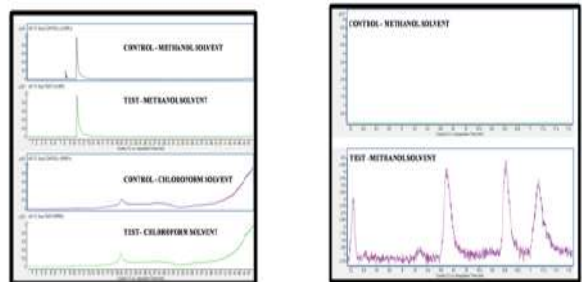
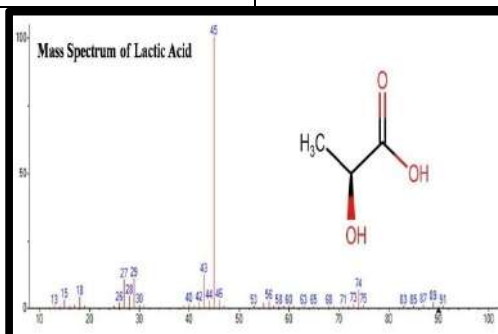


Fig 6(a) Components extracted from Lactobacillus





Thalassemias Clinical Description and Management

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ABSTRACT

The population distribution of thalassemia is changing due to changing demographics and increased migration from areas where thalassemia is more frequent to those where it is less prevalent. India bears a huge burden of hemoglobinopathies, and the most prevalent is thalassemia, which has some public health implications. As a result, it is critical to identify patients with thalassemia syndromes and thalassemia features in order to give early comprehensive care and avoid unnecessary interventions. A concerted effort to educate and raise awareness will continue to be required in diversified Indian population, both urban and rural.

Keywords: Hemoglobinopathies, Alpha Thalassemia, Beta Thalassemia, Weak Blood, Blood Transfusion, Iron Chelation





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INTRODUCTION

Hemoglobinopathies are all hereditary illnesses of hemoglobin (Hb) that are caused by a defect in one of the globin chains of the Hb molecule. They are classified into two types: quantitative defects (thalassemia syndromes, in which production is impaired) and qualitative defects (sickle cell syndrome, in which the structure of the globin chain is aberrant) [1]. Thalassemias are a diverse set of hereditary illnesses caused by a reduction in the production of the alpha or beta chains of hemoglobin (Hb). Thalassemia is an inherited condition, which means that at least one of the parents must be a carrier. It is caused by a genetic mutation or the loss of critical gene sequences [2]. The name thalassemia derived from a combination of two Greek words: Thalassa meaning the sea [3] that is the Mediterranean and anemia (“weak blood”). Another term found in literature, although infrequently, is Cooley’s anemia after the name of Prof. Cooley Thomas, a pediatrician in the USA who first described the clinical characteristics of this disorder in patients of Italian origin 1925 [4]. Thalassemia is a group of autosomal recessive conditions that result from mutations in one of the genes of the globin chains with impaired synthesis of these and are characterized by microcytic anemia of varying severity [5]. There are over 200 mutations identified as the culprits for causing thalassemias. Alpha thalassemia is caused by deletions of alpha-globin genes, and beta thalassemias are caused by a point mutation in splice site and promoter regions of the beta-globin gene on chromosome 11 [6]. The synthesis defect is either of alpha or beta globin chain, which together form hemoglobin A ($\alpha\alpha\beta\beta$). This causes reduced synthesis of hemoglobin and thus defective hemoglobinization of the erythrocytes, resulting in hypochromic, microcytic anaemia [7]. A defect in one or more of the four alleles coding for alpha-globin results in alpha-thalassemia. Depending on how many of the four genes are affected, the severity varies from no symptoms to a condition incompatible with life [7]. A defect in one of the two alleles that code for beta globin chain production results in beta-thalassemia. Over 200 different mutations in the gene have been described. Certain mutations in the beta globin gene do not result in a completely nullified beta globin synthesis. These mutations are designated B- as distinct from B+0-mutations resulting in a complete cessation of beta globin synthesis. Thus, B mutations usually give a somewhat milder phenotype+. Depending on the number and nature of the mutations, the clinical picture may vary from no symptoms to severe chronic transfusion-requiring hemolytic anaemia.

ALPHA THALASSEMIA

DEFINITION

Alpha-thalassemia is inherited as monogenic gene and an autosomal recessive disorder characterized by a microcytic hypochromic anaemia, and a clinical phenotype varying from almost asymptomatic to a lethal hemolytic anaemia [8]. Compound heterozygotes and some homozygotes have a moderate to severe form of alpha thalassemia called Hemoglobin H (HbH) disease. Hb Bart's hydrops foetalis is a lethal form in which no alpha-globin is synthesized [9].

ETIOLOGY

In normal people, four α globin genes, two on each copy of chromosome 16, regulate globin synthesis, and this genotype is indicated as $\alpha\alpha/\alpha\alpha$. The deletion of one ($-\alpha$) or both ($--$) α genes from the chromosome is the most common cause of alpha thalassemia. Point mutations in key areas of the $\alpha 2$ ($\alpha T\alpha$) or $\alpha 1$ (αT) genes can occasionally produce non-deletional thalassemia [10,11]. Thalassemia is caused by the deletion of the MCS-R regulatory elements (written as $(\alpha\alpha)T$); in all of these deletions, MCS-R2 is invariably eliminated and thus appears to be the key regulatory element [12]. When a mutation (or mutations) fully eliminates expression from a chromosome, this is referred to as $\alpha 0$ -thalassaemia, and when the mutation(s) just partially reduces expression from the chromosome, this is referred to as $\alpha +$ -thalassemia. Despite the fact that there are now 128 different molecular defects known to cause thalassemia and an ever-increasing number of potential interactions, the clinical phenotypes (broadly classified as thalassemia trait, HbH disease, and Hb Bart's hydrops foetalis) resulting from the interactions between these various molecular defects. The degree of globin chain deficit correlates extremely well with the severity of the clinical phenotype. Another essential factor to note is that interactions involving non-deletional variants of $\alpha +$ -thalassemia result in a more severe phenotype than those involving deletional forms of $\alpha +$ -thalassemia [13,14].





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OCCURRENCE

α thalassemia, like all common globin gene disorders (sickle cell trait and thalassemia), is prevalent in all tropical and subtropical parts of the world. In some locations, the α thalassemia carrier frequency may be as high as 80-90% of the population [15]. Because of discrepancies in the interactions of the numerous genetic abnormalities that cause α thalassemia, South East Asia, the Middle East, and the Mediterranean are the most affected by HbH illness. Similarly, Hb Bart's Hydrops foetalis syndrome is more common in South East Asia [16,17].

CLINICAL DESCRIPTION

Most people with α thalassemia have extremely minor clinical characteristics that are only noticeable when a regular full blood count is performed. Patients suffering from HbH illness have a diverse phenotype, while those suffering from Hb Bart's hydrops foetalis have a fatal form of anaemia.

α Thalassemia trait

Besides mild to severe microcytic hypochromic anaemia, carriers of α thalassemia, regardless of the molecular basis, are clinically asymptomatic, and the diagnosis is frequently found during a routine health check or pregnancy screening. Complaints associated with more severe anaemias, such as tiredness, drowsiness and difficulty in breathing, are uncommon and virtually always associated with other concurrent diseases [9].

HbH disease

Patients with HbH illness are more likely to be compound heterozygotes for two separate mutations or, less frequently, homozygotes for a moderately severe molecular abnormality. They often produce less than 30% of normal globin levels. HbH illness is distinguished by anaemia (2.6-13.3 g/dl) with varying quantities of HbH (0.8-40%), which is occasionally accompanied by Hb Bart's in the peripheral blood. Patients typically have splenomegaly, which is occasionally compounded by hypersplenism. Jaundice can occur in varying degrees, and children can experience growth retardation. Infections, leg ulcers, gall stones, folic acid deficiency, and acute hemolytic episodes in response to medications and infections are among the other problems [18].

Hb Bart's Hydrops Foetalis Syndrome

Infants with Hb Bart's hydrops foetalis syndrome have the most severe globin expression deficits. While it is most commonly caused by the inheritance of no globin genes from either parent, it can also be caused by the inheritance of a severe nondeletion mutation from one parent and no genes from the other. HbH hydrops syndrome is defined as patients who are on the borderline between severe HbH disease and Hb Bart's hydrops foetalis syndrome [19].

The clinical symptoms of a pale edematous infant with signs of heart failure and persistent intra-uterine anaemia will be present. Characteristic features are pronounced hepatosplenomegaly, brain growth retardation, skeletal and cardiovascular abnormalities, and massive placental enlargement. Infants with Hb Bart's hydrops foetalis syndrome often die in utero (23-38 weeks) or shortly after birth, while a few cases in which the infant is given intense life-support medication and blood transfusions have been documented. [20].

DIAGNOSIS

A complete blood count with red cell indices, HPLC or Hb electrophoresis, and eventually α/β -globin chain synthesis ratio measurement. Microcytic, hypochromic red blood cells (mean corpuscular volume 70 fL) that do not respond to iron supplementation are a significant indicator of minor, intermediate, or major thalassemia. It is therefore critical to assess the effect of iron supplementation by evaluating ferritin concentration and mean corpuscular volume in order to distinguish non-adherent individuals from those who require second line testing, regardless of apparent ethnic background [21]. Separation and quantification of hemoglobin fractions using high performance liquid chromatography or capillary electrophoresis constitutes second line testing [23]. Hemoglobin H disease (- α -/ α -) is characterized by a varying degree of pallor at birth, and laboratory testing reveals microcytic anaemia. Second-line testing reveals approximately 20% hemoglobin Bart's (γ 4) in the newborn period and varying quantities of hemoglobin H (β 4) later in adulthood. In the absence of iron deficiency and normal hemoglobin fractions in second line testing, the most likely diagnosis in individuals with mild microcytic anaemia will be a mild form of α





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thalassemia, which will be confirmed by DNA analysis. DNA (Gap-PCR technologies or direct DNA sequencing) analysis should be available to identify and confirm at-risk couples during prenatal testing and preimplantation genetic diagnosis.

MANAGEMENT

Alpha thalassemia trait

Carriers of α^{+} - or α^0 -thalassaemia alleles do not usually require treatment because their anaemia is either mild or absent due to a compensating high red blood cell count. On the other hand, once a α thalassemia trait diagnosis is made, there is a tendency to rule out iron deficiency as a possible cause of anaemia. Carriers of thalassemia might become anemic as a result of concurrent nutritional deficits, such as iron deficiency, folate insufficiency, or vitamin B12 deficiency, and should be handled accordingly.

HbH disease

HbH disease may appear to be a benign disorder, but recent research indicates that its clinical course is frequently more severe than previously recognize [23,24]. As previously stated, the type of mutation affects the clinical severity of HbH illness. The deletion type is the most frequent, and it generates a milder form of HbH illness. These individuals may require intermittent transfusion therapy, especially if they have multiple illnesses. Chronic transfusion therapy is quite rare in this population. Patients with non-deletional HbH disease, on the other hand, may have fairly severe splenomegaly, necessitating more frequent transfusions and, eventually, splenectomy [25]. According to some studies, nearly half of such people required recurrent transfusions, particularly in early childhood and later adulthood [26]. However, clinical diversity exists in both categories. Iron overload is uncommon in HbH disease patients (as compared to thalassemia), but it has been observed in older patients (>45 years) and those receiving regular blood transfusions].

Hb Bart's Hydrops Foetalis Syndrome

The majority of pregnancies in which the fetus with Bart's hydrops foetalis syndrome are terminated. In a very small number of cases (non-hydropic infants) hematopoietic stem cell transplantation is recommended [27]. Increased risk of both maternal and foetal morbidity should be taken into account when counselling couples at risk for having a child affected with this syndrome [28].

BETA THALASSEMIA

DEFINITION

Beta-thalassemia is one of most common autosomal recessive disorders worldwide. Different molecular mechanisms, most of which are base substitutions or small deletions or insertions of one or two nucleotides in the β -globin gene are responsible for β -thalassemia [29]. Moreover, it has been found that β -thalassemia mutations are relatively population specific, i.e., each ethnic group has its own set of common mutants [30,31]. Point mutations in the beta-globin gene cause beta thalassemia. The zygosity of the beta-gene mutation divides it into three categories [32]. Beta-thalassemia minor is caused by a heterozygous mutation (beta-plus thalassemia), in which beta chains are under produced. It is usually asymptomatic and mild. A homozygous mutation (beta-zero thalassemia) of the beta-globin gene results in the complete absence of beta chains in beta thalassemia major. The condition in between these two forms is known as beta-thalassemia intermedia, and it is characterized by mild to moderate clinical symptoms.

ETIOLOGY

Beta-thalassemia is an inherited ailment caused by mutations (over 200 have been found) or, in rare cases, deletions of the beta-globin gene (HbB) on chromosome 11. These are mostly point mutations that alter the HbB gene and gene product's transcriptional regulation, translation, and splicing [33]. The bi-allelic inheritance of two copies of the beta-globin gene, one on each chromosome 11, as well as the varied pool of illness-causing mutations, contribute to the





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disease severity spectrum. Beta (+) for decreased production and beta (0) for missing production is the genotypic variability of beta-globin synthesis. The phenotypic variability is classified as small, intermedia, or major. Beta-thalassemia minor is caused by heterozygosity in which one beta-globin gene is unaffected and one is afflicted, either beta (+) or beta (0). Intermedia and major are caused by homozygosity or compound heterozygosity with beta (+) or beta (0). These two are distinguished clinically by the severity of anemia and not by genotype.

OCCURRENCE

Populations in the Mediterranean, Middle East, Transcaucasus, Central Asia, Indian subcontinent, and Far East have a high prevalence. [32]. It is also relatively common among African-descent people [34]. Cyprus (14%), Sardinia (12%), and South East Asia have the highest incidences [32]. In India, beta-thalassemias and sickle cell disease represent a severe health burden. According to the Census of India 2011, the average prevalence of beta-thalassemia carriers is 3-4%, which equates to 35 to 45 million carriers in our multi-ethnic, culturally and linguistically diversified population of 1.21 billion people, which also includes around 8% of tribal communities. Several ethnic groups have significantly higher rates (4-17%). [35,36]. According to estimates, there would be approximately 100,000 patients with beta-thalassemia syndrome and approximately 150,000 cases of sickle cell disease in this huge country [37,38]. The March of Dimes Global Report on Birth Defects has estimated that the prevalence of pathological hemoglobinopathies in India is 1.2 per 1000 live births. It has been suggested that there would be 32,400 babies with a serious hemoglobin disorder born each year based on 27 millions births per year in India [39,40].

CLINICAL DESCRIPTION

Thalassemia major and thalassemia intermedia are phenotypes of homozygous or genetic heterozygous compound beta-thalassemias. Individuals with thalassemia major are usually diagnosed within the first two years of life and require RBC transfusions on a regular basis to survive. Patients with thalassemia intermedia present later and do not require regular transfusions.

Beta-thalassemia major

Clinical presentation of thalassemia major occurs between 6 and 24 months. Affected infants fail to thrive and become progressively pale [41]. Untreated thalassemia major patients have growth retardation, pallor, jaundice, poor musculature, hepatosplenomegaly, leg ulcers, the formation of masses from extra medullary hematopoiesis, and skeletal abnormalities caused by bone marrow expansion. A peripheral blood smear reveals anisocytosis, poikilocytosis [spiculated tear drop and elongated cells], and nucleated red blood cells [i.e., erythroblasts] in addition to microcytosis and hypochromia. If a regular transfusion program is started with a minimum Hb concentration of 9.5 to 10.5 g/dL, growth and development should be normal for the next 10 to 12 years [42]. Iron overload problems can occur in transfused individuals. Iron overload complications in children include growth retardation and failure or delay in sexual development. Later iron overload complications include heart involvement (dilated cardiomyopathy or, less commonly, arrhythmias), liver involvement (fibrosis and cirrhosis), and endocrine gland involvement (diabetes mellitus, hypogonadism, and insufficiency of the parathyroid, thyroid, pituitary, and, less commonly, adrenal glands) [43]. Other risks include hypersplenism, chronic hepatitis (caused by virus infection with hepatitis B and/or C), HIV infection, venous thrombosis, and osteoporosis. Patients with liver viral infection and iron excess are at a higher risk of developing hepatocellular cancer [44].

Beta-thalassemia intermedia

Patients have a moderate anaemia and show a markedly heterogeneous hematological picture, ranging in severity from that of the beta thalassemia carrier state to that of thalassemia major. Gallstones are more common in thalassemia intermedia patients than in thalassemia major individuals due to poor erythropoiesis and peripheral hemolysis [45]. Patients with thalassemia intermedia are more likely to develop leg ulcers and have a higher risk of





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thrombosis than those with thalassemia major, especially if splenectomised. Deep vein thrombosis, portal vein thrombosis, stroke, and pulmonary embolism are examples of such events [46].

Beta-thalassemia minor

Carriers of thalassemia minor are usually clinically asymptomatic, but sometimes have a mild anaemia when both parents are carriers there is a 25% risk at each pregnancy of having children with homozygous thalassemia. The characteristic hematological features are microcytosis (reduced red blood cell volume), hypochromia (reduced red blood cell Hb content) and increased HbA2 level.

DIAGNOSIS

Hematologic Diagnosis

Microcytic anaemia is revealed by RBC indices. Thalassemia major is distinguished by a low Hb level (7 g/dl), a mean corpuscular volume (MCV) greater than 50 fl, and a mean corpuscular Hb (MCH) greater than 12 pg. Thalassemia intermedia is defined by a Hb level between 7 and 10 g/dl, an MCV level between 50 and 80 fl, and an MCH level between 16 and 24 pg. Thalassemia minor is distinguished by low MCV and MCH levels and an elevated Hb A2 level [47]. Microcytosis, hypochromia, anisocytosis, poikilocytosis (spiculated tear-drop and elongated cells), and nucleated RBC (i.e., erythroblasts) are observed in affected people. The quantity of erythroblasts is proportional to the degree of anaemia and is significantly increased following splenectomy. Carriers have less severe morphologic alterations in their RBCs than affected individuals. Normally, erythroblasts are not visible. Qualitative and quantitative hemoglobin analysis [by cellulose acetate electrophoresis and DE-52 micro-chromatography or HPLC] identifies the amount and type of hemoglobin present.

Molecular Genetic Testing

Targeted mutation analysis; more than 200 distinct HBB gene mutations can produce β -thalassemias. The β -thalassemias can be caused by more than 200 different HBB gene mutations [48]; however, the prevalent molecular defects are limited in each at-risk population. Reverse dot blot analysis or primer-specific amplification ARMS PCR, real-time PCR, or microarray technology are the most often utilized methodologies [48,50]. Mutations in the HBB coding area and related flanking regions are detected using sequence analysis, where the sensitivity is 99.9%. Deletions of variable extent of the HBB gene or of the beta-globin gene cluster that result in β -thalassemia or in the complex β -thalassemias called $\gamma\delta\beta$ -thalassemia and $\delta\beta$ -thalassemia are rare causes of β -thalassemia. Deletions of the HBB gene or the beta-globin gene cluster that result in β -thalassemia or in the complex β -thalassemias called $\gamma\delta\beta$ -thalassemia and $\delta\beta$ -thalassemia are rare causes of β -thalassemia.

MANAGEMENT

Beta-thalassemia major

In 2022 the Thalassemia International Federation (TIF) published guidelines for the clinical management of thalassemia major. The cornerstones of treatment are: (a) Regular hyper transfusion to maintain a hemoglobin level higher than 95 g/L, (b) Iron chelation to prevent overload syndrome, (c) Care by a multidisciplinary team (hematologist, paediatric hematologist, specialized nurse, social worker, psychologist, genetic counsellor, cardiologist, and hepatologist) [42]. Transfusion therapy aims to rectify anaemia, decrease erythropoiesis, and prevent gastrointestinal iron absorption, which happens in non-transfused patients as a result of enhanced, but unsuccessful, erythropoiesis. In patients with a confirmed diagnosis of thalassemia, the decision to begin transfusion should be based on the presence of severe anaemia (Hb 7 g/dl for more than two weeks, eliminating other contributory factors such as infections). Several transfusion regimens have been developed throughout the years, but the most frequently recognized targets a pre-transfusional Hb level of 9 to 10 g/dl and a post-transfusion level of 13 to 14 g/dl. This eliminates growth retardation, organ damage, and bone deformities, allowing for normal activity and life quality [42].





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Beta-thalassemia intermedia

Individuals with thalassemia intermedia are treated symptomatically [51]. Because hypersplenism can lead to increasing anaemia, slowed growth, and mechanical disruption from the huge spleen, splenectomy is an important part of thalassemia intermedia therapy. Immunization against the aforementioned pathogens, antibiotic prophylaxis, and early antibiotic treatment for fever and malaise are all part of the prevention of post-splenectomy sepsis. For ulcer treatment, regular blood transfusions, zinc supplementation and pentoxifylline, as well as the use of an oxygen chamber, have been advocated. Hydroxycarbamide provides some benefit, either alone or in combination with erythropoietin. Chelation therapy is initiated when the serum ferritin concentration exceeds 300 ng/ml or when iron overload is demonstrated by direct or indirect methods in individuals with thalassemia intermedia [52]. Supplementary folic acid can be prescribed to patients with thalassemia intermedia to prevent deficiency from hyperactive bone marrow. Indications for transfusion in β thalassemia intermedia [53]; includes hemoglobin concentration <50 g/L, falling hemoglobin level with profound enlargement of the spleen, growth failure or poor performance at school, diminished exercise tolerance, failure of secondary development in parallel with bone age, severe bone changes, pregnancy, infection, and other specific complications: heart failure, pulmonary complications, hypertension, thromboembolic disease, leg ulcers, priapism

REFERENCES

1. Saxena R, Banerjee T, Aniyery RB. Thalassemia and its Management during Pregnancy. *World J Anemia* 2017;1(1):5-17.
2. Bajwa H, Basit H. Thalassemia. 2023. In: *StatPearls* [Internet]. Treasure Island (FL): StatPearls Publishing; 2023 Jan-. PMID: 31424735.
3. Cooley TB, Lee P. A series of cases of splenomegaly in children with anemia and peculiar bone changes. *Trans Am Pediatr Soc.* 1925;37:29-30
4. Cooley TB, Witwer ER, Lee P. Anemia in children with splenomegaly and peculiar change in bones: report of case. *Am J Dis Child.* 1927;34(3):347-363.
5. Luk'yanenko V, Droogh M, Overgaard UM. [Thalassaemia and pregnancy]. *Ugeskr Laeger.* 2017 Mar 20;179(12):V04160280.
6. Jalil T, Yousafzai YM, Rashid I, Ahmed S, Ali A, Fatima S, Ahmed J. Mutational Analysis of Beta Thalassaemia by Multiplex Arms-PcrIn Khyber Pakhtunkhwa, Pakistan. *J Ayub Med Coll Abbottabad.* 2019;31(1):98-103.
7. Poole JH. Thalassemia and pregnancy. *J Perinat Neonatal Nurs.* 2003;17(3):196-208.
8. Hartevelde CL, Higgs DR. Alpha-thalassaemia. *Orphanet J Rare Dis.* 2010;5:13.
9. Birgens H, Ljung R. The thalassaemia syndromes. *Scand J Clin Lab Invest.* 2007;67(1):11-25.
10. Hall GW, Higgs DR, Murphy P, Villegas A, de Miguel A. A mutation in the polyadenylation signal of the alpha 2 globin gene (AATAAA \rightarrow AATA \rightarrow) as a cause of alpha thalassaemia in Asian Indians. *Br J Haematol.* 1994;88(1):225-7.
11. Hartevelde CL, Losekoot M, Haak H, Heister GA, Giordano PC, Bernini LF. A novel polyadenylation signal mutation in the alpha 2-globin gene causing alpha thalassaemia. *Br J Haematol.* 1994;87(1):139-143.
12. Higgs DR. The molecular basis of α -thalassemia. *Cold Spring Harbor Perspectives in Medicine.* 2013 Jan;3(1):a011718.
13. Eng B, Patterson M, Walker L, Hoppe C, Azimi M, Lee H, Giordano PC, Waye JS. Three new alpha-thalassemia point mutations ascertained through newborn screening. *Hemoglobin.* 2006;30(2):149-153.
14. Henderson S, Chapple M, Rugless M, Fisher C, Kinsey S, Old J. Haemoglobin H hydrops fetalis syndrome associated with homozygosity for the alpha2-globin gene polyadenylation signal mutation AATAAA \rightarrow AATA \rightarrow . *Br J Haematol.* 2006;135(5):743-5.
15. Bernini LF. Geographic distribution of alpha thalassemia. In: *Disorders of hemoglobin: genetics, pathophysiology, and clinical management.* Steinberg MH, Forget PG, Higgs DR, Nagel RL, editors. UK: Cambridge University Press; 2001.



**Mohammed Basheir Ishag Mohammed et al.,**

16. Liao C, Wei J, Li Q, Li J, Li L, Li D. Nonimmune hydrops fetalis diagnosed during the second half of pregnancy in Southern China. *Fetal Diagn Ther.* 2007;22(4):302-5.
17. Suwanrath-Kengpol C, Kor-anantakul O, Suntharasaj T, Leetanaporn R. Etiology and outcome of non-immune hydrops fetalis in southern Thailand. *GynecolObstet Invest.* 2005;59(3):134-7.
18. Laosombat V, Viprakasit V, Chotsampancharoen T, Wongchanchailert M, Khodchawan S, Chinchang W, Sattayasevana B. Clinical features and molecular analysis in Thai patients with HbH disease. *Ann Hematol.* 2009;88(12):1185-92.
19. McBride KL, Snow K, Kubik KS, et al. Hb Dartmouth [α 66(E15)Leu \rightarrow Pro (α 2) (CTG \rightarrow CCG)]: a novel α 2-globin gene mutation associated with severe neonatal anemia when inherited in trans with Southeast Asian α -thalassemia-1. *Hemoglobin.* 2001;25(4):375-382.
20. Peters M, Heijboer H, Smiers F, Giordano PC. Diagnosis and management of thalassaemia. *BMJ.* 2012;344:e228.
21. Ryan K, Bain BJ, Worthington D, James J, Plews D, Mason A, Roper D, Rees DC, de la Salle B, Streetly A; British Committee for Standards in Haematology. Significant haemoglobinopathies: guidelines for screening and diagnosis. *Br J Haematol.* 2010;149(1):35-49.
22. Slomp J, Bosschaart A, Dousma M, van ZR, Giordano PC, Bergh FA van den. [Acute anaemia in a Vietnamese patient with α -thalassaemia and a parvovirus infection] *NederlandsTijdschrift Voor Geneeskunde.* 2006;150(28):1577-1582.
23. Chen FE, Ooi C, Ha SY, Cheung BM, Todd D, Liang R, Chan TK, Chan V. Genetic and clinical features of hemoglobin H disease in Chinese patients. *N Engl J Med.* 2000;343(8):544-50.
24. Cohen AR, Galanello R, Pennell DJ, Cunningham MJ, Vichinsky E. Thalassaemia. *Hematology Am Soc Hematol Educ Program.* 2004:14-34.
25. Lau YL, Chan LC, Chan YY, Ha SY, Yeung CY, Waye JS, Chui DH. Prevalence and genotypes of α - and β -thalassaemia carriers in Hong Kong – implications for population screening. *N Engl J Med.* 1997;336(18):1298-301.
26. Zhou X, Ha SY, Chan GC, et al. Successful mismatched sibling cord blood transplant in Hb Bart's disease. *Bone Marrow Transplantation.* 2001;28(1):105-107.
27. Lee SY, Li CK, Ling SC, Shiu YK. Survival of homozygous α -thalassaemia with aplasia/hypoplasia of phalanges and jejunal atresia. *J Matern Fetal Neonatal Med.* 2009;22(8):711-3.
28. Thein SL, Hesketh C, Wallace RB, Weatherall DJ. The molecular basis of thalassaemia major and thalassaemia intermedia in Asian Indians: application to prenatal diagnosis. *Br J Haematol.* 1988;70(2):225-31.
29. Fucharoen S, Winichagoon P. Haemoglobinopathies in southeast Asia. *Indian J Med Res.* 2011;134(4):498-506.
30. Colah R, Gorakshakar A, Phanasgaonkar S, D'Souza E, Nadkarni A, Surve R, Sawant P, Master D, Patel R, Ghosh K, Mohanty D. Epidemiology of β -thalassaemia in Western India: mapping the frequencies and mutations in sub-regions of Maharashtra and Gujarat. *Br J Haematol.* 2010;149(5):739-47.
31. Pines M, Sheth S. Clinical Classification, Screening, and Diagnosis in β -Thalassaemia and Hemoglobin E/ β -Thalassaemia. *Hematol Oncol Clin North Am.* 2023;37(2):313-325.
32. Cao A, Galanello R. β -thalassaemia. *Genet Med.* 2010;12(2):61-76.
33. Weatherall DJ, Clegg JB. *The Thalassaemia Syndromes.* Oxford: Blackwell Scientific Publications 2001.
34. Flint J, Harding RM, Boyce AJ, Clegg JB. The population genetics of the haemoglobinopathies. *Baillieres Clin Haematol.* 1998;11(1):1-51.
35. Madan N, Sharma S, Sood SK, Colah R, Bhatia LH. Frequency of β -thalassaemia trait and other hemoglobinopathies in northern and western India. *Indian J Hum Genet.* 2010;16(1):16-25.
36. Colah RB, Gorakshakar A. Control of Thalassaemia in India. *Thalassaemia Reports.* 2014; 4(2):1955.
37. Colah R, Mukherjee M, Ghosh K. Sickle cell disease in India. *Curr OpinHematol.* 2014;21(3):215-23.
38. Verma IC, Saxena R, Kohli S. Past, present & future scenario of thalassaemic care & control in India. *Indian J Med Res.* 2011;134(4):507-21.
39. PRB. World population data sheet. Population Reference Bureau; 2010. Washington DC.
40. Grow K, Vashist M, Abrol P, Sharma S, Yadav R. β thalassaemia in India: current status and challenges ahead. *Int J Pharm Pharm Sci.* 2014;6(4):28-33.
41. Galanello R, Origa R. β -thalassaemia. *Orphanet J Rare Dis.* 2010;5:11.



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42. Farmakis D, Porter J, Taher A, Domenica Cappellini M, Angastiniotis M, Eleftheriou A. 2021 Thalassaemia International Federation Guidelines for the Management of Transfusion-dependent Thalassemia. *Hemasphere*. 2022 Jul 29;6(8):e732.
43. Marengo-Rowe AJ. The thalassaemias and related disorders. *Proc (Bayl Univ Med Cent)*. 2007;20(1):27-31.
44. Borgna-Pignatti C, Vergine G, Lombardo T, Cappellini MD, Cianciulli P, Maggio A, Renda D, Lai ME, Mandas A, Forni G, Piga A, Bisconte MG. Hepatocellular carcinoma in the thalassaemia syndromes. *Br J Haematol*. 2004;124(1):114-7.
45. Galanello R, Piras S, Barella S, Leoni GB, Cipollina MD, Perseu L, Cao A. Cholelithiasis and Gilbert's syndrome in homozygous beta-thalassaemia. *Br J Haematol*. 2001;115(4):926-8.
46. Taher AT, Otrrock ZK, Uthman I, Cappellini MD. Thalassemia and hypercoagulability. *Blood Rev*. 2008;22(5):283-92.
47. Galanello R, Melis MA, Ruggeri R, Addis M, Scalas MT, Maccioni L, Furbetta M, Angius A, Tuveri T, Cao A. Beta 0 thalassemia trait in Sardinia. *Hemoglobin*. 1979;3(1):33-46.
48. Huisman THJ, Carver MFH, Baysal E. A Syllabus of Thalassemia Mutations. The Sickle Cell Anemia Foundation, Augusta, GA 1997.
49. Old J, Harteveld CL, Traeger-Synodinos J, Petrou M, Angastiniotis M, Galanello R. Prevention of Thalassaemias and Other Haemoglobin Disorders: Volume 2: Laboratory Protocols [Internet]. 2nd ed. Nicosia (Cyprus): Thalassaemia International Federation; 2012.
50. Ye BC, Zhang Z, Lei Z. Molecular analysis of alpha/beta-thalassemia in a southern Chinese population. *Genet Test*. 2007;11:75-83.
51. Borgna-Pignatti C. Modern treatment of thalassaemia intermedia. *Br J Haematol*. 2007;138(3):291-304.
52. Origa R, Galanello R, Ganz T, Giagu N, Maccioni L, Faa G, Nemeth E. Liver iron concentrations and urinary hepcidin in beta-thalassemia. *Haematologica*. 2007;92(5):583-8.
53. Cao A. Carrier screening and genetic counselling in beta-thalassemia. *Int J Hematol*. 2002;76 Suppl 2:105-13.





Assessment of Herbal Extract of Guava Leaves for Maintaining Good Oral Health

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ABSTRACT

Guava leaves have long been valued for their numerous health benefits, particularly in maintaining good oral health. Packed with potent compounds like antioxidants, anti-inflammatory agents, and antimicrobial properties, guava leaves offer a natural solution for oral hygiene. The leaves' antimicrobial properties help in fighting off bacteria responsible for plaque formation and gum diseases, reducing the risk of cavities and gingivitis. Additionally, the anti-inflammatory nature of guava leaves aids in soothing gum inflammation and relieving discomfort associated with oral conditions. Regular use of guava leaves can contribute to fresher breath and overall oral hygiene. Furthermore, guava leaves contain compounds like flavonoids and tannins, which promote oral health by strengthening gums and preventing periodontal diseases. Incorporating guava leaves into your oral care routine, whether through chewing or as a mouthwash, can be a natural and effective way to maintain optimal oral health and hygiene. According to the results of the agar well diffusion method against isolates, Guava leaf extract showed antibacterial activity. After 24 hours of incubation, all the extracts of Guava were effective against isolates 1.1A, 2.1A, 2.1B, 3.1A, and 4.1A, except for the aqueous extraction, which was not effective against isolate 5.1C. However, after 48 hours of incubation, isolate 1.1A overcame the inhibition effect of ethyl acetate and methanol extractions of Guava Leaves, and isolate 4.1A overcame the inhibition effect of aqueous extraction. Other extractions showed inhibition on all the isolates up to 72 hours. It was also noted that ampicillin was found to be responsive to all test strains of bacteria, used as a positive control. Conversely, the negative control, DMSO, was selected since it does not have any inhibitory effect. This data supports



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the potential antibacterial activity of Guava leaf extract, further substantiating its potential application in oral health products. The observed effectiveness against the studied microorganisms, even after 72 hours of incubation, indicates a sustained antibacterial effect. This aligns with the potential use of Guava leaf extract for maintaining good oral health, particularly in combating oral pathogens.

Keywords: Guava leaves, Antimicrobial Properties, Oral Health, Antimicrobial assay, Methanolic extract, Aqueous extract, Ethyl Acetate Extract.

INTRODUCTION

Oral health is a key indicator of overall health, well-being, and quality of life. WHO defines oral health as “a state of being free from chronic mouth and facial pain, oral and throat cancer, oral infection and sores, periodontal (gum) disease, tooth loss, and other disease and disorder that limits an individual capacity in biting, chewing, smiling, speaking and psychosocial wellbeing”. World Health Organization (2003). Guava, or *Psidium guajava*, is a phytotherapeutic plant. Poor man's apple is another name for it (Ismail *et al.*, 2012). It is a member of the Myrtaceae family, which has around 3800 plant species and at least 133 genera (Jayakumari *et al.*, 2012). It is believed to have active ingredients that aid in the management and treatment of a number of illnesses (Biswas *et al.*, 2013). Antioxidant, hepatoprotective, antiallergy, antimicrobial, antigenotoxic, antiplasmodial, cytotoxic, antispasmodic, cardioactive, anticough, antidiabetic, anti-inflammatory, and antinociceptive properties are all reported to be present in the leaves of the *P. guajava* Linn plant (Jayakumari *et al.*, 2012). Additionally, it is used to treat wounds, sore throats, issues from vomiting during menstruation, and skin sores. The infusion decoction prepared from the tree's leaves and/or bark has been used to cure malaria, dysentery, and diarrhoea. It is anticipated that guava's medicinal applications stem from the fruit's potent constituents (Elekwa *et al.*, 2009).

Maintaining good oral health is crucial for all. One potential natural solution for oral health maintenance is the herbal extract of Guava leaves (Pereira *et al.*, 2013). Research has shown that Guava leaves contain various compounds such as tannins, saponins, flavonoids, and phenols, which possess antibacterial, anti-inflammatory, and antioxidant properties. These properties make guava leaf extract a promising candidate for oral health products. The antibacterial properties can help in fighting oral pathogens, the anti-inflammatory properties may aid in reducing gum inflammation, and the antioxidant properties can contribute to overall oral health by reducing oxidative stress. Moreover, the traditional use of guava leaves by indigenous groups in different cultures for oral health purposes adds to the historical evidence supporting its potential benefits (Díaz-de-Cerio *et al.*, 2017). It is important to consider that the quality and composition of herbal extracts can vary based on environmental factors, so further research is needed to ensure consistency and efficacy in the use of guava leaf extract for oral health. There have been reports that guava leaves can be utilised to maintain dental hygiene (Jebashree *et al.*, 2011). Guava leaves are sensitive, so people chew them to stop bad breath and gum bleeding. Triterpenes, tannins, phenols, essential oils, flavonoids, vitamins, saponins, carotenoids, lectins, fibres, and fatty acids are all present in guavas. Nonetheless, the presence of flavonoids, lutein, zeaxanthin, and lycopene is credited with a number of pharmacological effects. Flavonoids, particularly quercetin, which is the main ingredient responsible for the antibacterial activity, are abundant in guava tree leaves (Esimone *et al.*, 2007). According to Mailoa *et al.* (2014), it has tannins, which have been shown to be effective against a variety of pathogens, including *Staphylococcus aureus* and *Escherichia coli*. Further research and clinical studies are needed to better understand the potential benefits of guava leaf extract for oral health. Additionally, the development of oral care products incorporating guava leaf extract could offer a natural and effective alternative for maintaining good oral hygiene (Díaz-de-Cerio *et al.*, 2017) (Gutiérrez *et al.*, 2008).





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MATERIALS AND METHODS

Preparation of Guava leaves powder

Young leaves of guava were plucked from the plants. Guava leaves were cleaned with tap water, given a Tween 20 treatment to get rid of any surface debris, dried in the shade, and then crushed into a coarse powder using an electric blender.

Preparation of extract of Dried Guava Leaves

For extraction 1:3 w/v product powder and Methanol, Ethyl Acetate and Water were taken separately in three flasks, mixed thoroughly. The mixture flasks were kept for 3-4 days with constant agitation at specific time intervals. The extracts were filtered using muslin cloth. The filtrates were concentrated separately 40°C using heating Mantle. After this process, the extracts become semi-solid which has been refrigerated for further use.

Preparation of Guava extract Solution for testing Antimicrobial Activity

Guava crude extract were dissolved in DMSO (Dimethyl sulfoxide) to make the dilution: 250 mg/ml

Positive and Negative Control

For anti-microbial activity positive control and negative control were taken Ampicillin 20mg/ml and DMSO respectively.

Microorganism Revival

Total of 9 bacterial cultures were collected from Supragingival biofilm samples from 5 Individuals based on different colony morphology. Biochemical characterization was done for all isolates. From Isolated 9 cultures, 6 cultures were taken for Antimicrobial activity: 1.1A, 2.1A, 2.1B, 3.1A, 4.1A, 5.1C. As per Biochemical Characteristics cultures were identified as: The bacterial strains were maintained in Nutrient Broth (at pH 7.4±0.2) at 36±1°C and All culture media was procured from HiMedia Laboratories and prepared as per given procedure. The stock culture slants were maintained at 4°C in the laboratory.

Bacteria and Growth Condition

The stock culture of *Klebsiella pneumoniae* subspecies ozaenae, *Klebsiella terrigena*, *Proteus myxofaciens*, *Proteus mirabilis*, *Klebsiella terrigena*, *Escherichia coli*, inactive used in the present study. Muller Hinton agar was used to isolate the cultures. Subculturing of isolates were done by incubating them at 35°C to 37°C for 48 to 72 hours. The agar plates were inoculated and incubated for 48 hours, and reincubated for another 2 to 4 days, so as to allow those slow-growing organisms to form colonies.

Antimicrobial Assay of Plant Extracts

Antimicrobial assay of water, methanol and ethyl acetate extracts of Guava leaves were performed by agar well diffusion method in Muller Hinton agar (MHA) plates. For culture inoculation in MHA agar plate spread plate method was followed. Different concentration (250 mg/ml) of Guava crude extract in DMSO were inoculated in 8mm well on culture inoculated agar plate (Maragathavalli *et al*, 2012). For anti-microbial activity positive control and negative control were taken Ampicillin 20mg/ml and DMSO respectively. Inoculated plates were incubated 35°C for 48hrs. After 48hrs and 72 hrs observations were taken by zone of inhibitions (Perez *et al*, 1990; Reddy *et al*, 2013). The assays were carried out under aseptic conditions maintaining required biohazard level.

RESULTS AND DISCUSSION

In various civilizations around the world, medicinal plants have been utilized for thousands of years as traditional therapies for a wide range of illnesses. They still serve as the main source of medication in rural areas of developing nations (Chitme, 2003). In poor nations, traditional medicines are used by about 80% of the population (Kim, 2005).



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The potential use of many traditional medicinal plants in the prevention or treatment of oral disorders has been examined. Several studies have examined the effectiveness of plant extracts and products against particular oral pathogens, while others have concentrated on the products' capacity to prevent the development of dental biofilms by reducing the adhesion of microbial pathogens to the tooth surface, which is a key step in the formation of dental plaque and the development of tooth decay and periodontal diseases (Steinberg et al. 2004). The ability of the test compound to inhibit the growth of common oral pathogens is evaluated in assays used to determine the antimicrobial properties of medicinal plant extracts and natural products used to treat or prevent oral diseases. These tests are typically quick and simple to perform. Popular agar diffusion techniques, such as disc diffusion and well diffusion, have been employed in a lot of investigations. The agar well-diffusion method, which has been shown to be more sensitive than other techniques like the disc diffusion method, was used in this work for the microbiological assay (Valgas et al., 2007). Zones of growth inhibition around the disc or well after the proper incubation show antibacterial action (Palombo, 2009). The guava leaves had been reported to contain essential oils, saponins, flavonoids, nerolidiol, β -sitosterol, ursolic, crategolic and guayavolic acid. These substances were reported to have strong antibacterial action (Gutiérrez et al., 2008). Prabu et al., have demonstrated Guajaverin, a flavonoid in the methanolic extract of leaves of guava that exhibited strong antibacterial activity against caries causing *Streptococcus mutans* (Prabu et al., 2006). Thus, this study attempted to evaluate the efficacy of guava leaves, a rich source of antibacterial substances against the isolates. Graph 1, and 2 display the results of the agar well diffusion method against the six isolated microorganisms, Guava leaf extract showed antibacterial activity. As per the methods plates were inoculated with 6 isolated cultures and all extractions were inoculated into the well, plates were incubated at 35 °C. Observations were made after inoculation up to 72 hrs.

As per the results all the Extract of Guava were effective against isolates (1.1A, 2.1A, 2.1B, 3.1A, 4.1A, and 5.1C) after 24 hrs incubation except aqueous extraction, it was not effective against isolate 5.1C. But after 48hrs incubation isolate 1.1A overcame the inhibition effect of Ethyl Acetate and Methanol extractions of Guava Leaves and Isolate 4.1A Overcame the inhibition effect of Aqueous extraction, other extractions showed inhibition on all the Isolates up to 72 hrs. Ampicilin was found to be responsive to all test strains of bacteria, used as Positive control. The negative control, DMSO, was selected since it had no zone of inhibition against the studied bacteria. This information confirms guava leaf extract's possible antibacterial action and strengthens the evidence for its use in oral health products. Even after 72 hours of incubation, the observed efficiency against the investigated microorganisms suggests a persistent antibacterial activity. This is consistent with the possible application of guava leaf extract in oral health maintenance, namely in the fight against oral infections. Overall, the assessment suggests that guava leaf extract may hold promise for maintaining good oral health due to its antibacterial, anti-inflammatory, and antioxidant properties. However, more research is needed to fully understand its potential benefits and to develop effective oral care products incorporating guava leaf extract. In conclusion, the herbal extract of Guava leaves shows potential for maintaining good oral health due to its antibacterial, anti-inflammatory, and antioxidant properties (Díaz-de-Cerio et al., 2017; Biswas et al., 2013; Gómez et al., 2020; Jiménez-Escrig et al., 2001)

REFERENCES

1. Continuous improvement of oral health in the 21st century– the approach of the WHO Global Oral Health Programme. The World Oral Health Report 2003.
2. Ismail M, Minhas PS, Khanum F, Sahan VM, Sowmya C. (2012) Antibacterial activity of leaves extract of guava (*Psidium guajava*). *Int J Res Pharm Biomed Sci* 2012;3:1-2.
3. Jayakumari S, Anbu J, Ravichandiran V, Nithya S, Anjana A, Sudharani D. (2012) Evaluation of toothache activity of methanolic extract and its various fractions from the leaves of *Psidium guajava* Linn. *Int J Pharm Bio Sci* 2012;3:238-49.
4. Biswas B, Rogers K, McLaughlin F, Daniels D, Yadav A. (2013) Antimicrobial activities of leaf extracts of Guava (*Psidium guajava* L.) on two gram-negative and gram-positive bacteria. *Int J Microbiol*;746165.





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5. Elekwa I, Okereke SC, Ekpo BO. (2009) Preliminary phytochemical and antimicrobial investigations of the stem bark and leaves of *Psidium guajava* L. *J Med Plant Res*;3:45-8.
6. Pereira, G. A., Chaves, D. S. A., Silva, T. M. E., Motta, R. E. A., Silva, A. B. R. D., Patricio, T. C. D. C., Fernandes, A. J. B., Coelho, S. M. O., Ożarowski, M., Cid, Y. P., & Karpiński, T. M. (2023). Antimicrobial Activity of *Psidium guajava* Aqueous Extract against Sensitive and Resistant Bacterial Strains. *Microorganisms*, 11(7), 1784. <https://doi.org/10.3390/microorganisms11071784>
7. Díaz-de-Cerio, E., Verardo, V., Gómez-Caravaca, A. M., Fernández-Gutiérrez, A., & Segura-Carretero, A. (2017). Health Effects of *Psidium guajava* L. Leaves: An Overview of the Last Decade. *International journal of molecular sciences*, 18(4), 897. <https://doi.org/10.3390/ijms18040897>
8. Jebashree HS, Kingsley SJ, Sathish ES, Devapriya D. (2011) Antimicrobial activity of few medicinal plants against clinically isolated human cariogenic pathogens-An in vitro study. *ISRN Dent*;541421.
9. Esimone CO, Nworu CS, Ekong US, Iroha IR, Okolin CS. (2007) A case for the use of herbal extracts in oral hygiene: The efficacy of *Psidium guajava*-based mouthwash formulation. *Res J Appl Sci*;2:1143-7.
10. Mailoa MN, Mahendradatta M, Laga A, Djide N. (2014) Antimicrobial activities of tannins extract from guava leaves (*Psidium guajava* L.) on pathogens microbial. *Int J Sci Technol Res*;3:236-41.
11. Gutiérrez, R. M., Mitchell, S., & Solis, R. V. (2008). *Psidium guajava*: a review of its traditional uses, phytochemistry and pharmacology. *Journal of ethnopharmacology*, 117(1):1-27. <https://doi.org/10.1016/j.jep.2008.01.025>
12. Maragathavalli, S., Brindha, S., Kaviyarasi, N.S., B. Annadurai, B. & Gangwar, S.K. (2012). Antimicrobial Activity in Leaf Extract of Neem (*Azadirachta indica* Linn.). *International Journal of Science and Nature*, 3(1): 110-113
13. Perez, C., Pauli, M. and Bazerque, P. (1990) An Antibiotic Assay by Agar Well Diffusion Method. *Acta Biologicae et Medicinae Experimentalis*, 15, 113-115.
14. Reddy, R. R. Y., Kumari, K. C., Lokanatha, O., Mamatha, S., & Damodar Reddy, D. C. (2013). Antimicrobial activity of *Azadirachta Indica* (neem) leaf, bark and seed extracts. *International Journal of Research in Phytochemistry & Pharmacology*, 3:1-4.
15. Chitme, H. R. Chandra, R. and Kaushik, S. (2003) "Studies on antidiarrheal activity of *calotropis gigantea* R. Br. in experimental animals," *Journal of Pharmacy & Pharmaceutical Sciences*, 7:70-75.
16. Kim, H.-S. (2005) "Do not put too much value on conventional medicines," *Journal of Ethnopharmacology*, 100(1-2):37-39.
17. Steinberg, D. Feldman, M. Ofek, I. and Weiss, E. I. (2004) "Effect of a high-molecular-weight component of cranberry on constituents of dental biofilm," *Journal of Antimicrobial Chemotherapy*, 54:(1):86-89.
18. Valgas C, Machado de Souza S, Samania EF, Samania A. (2007) Screening methods to determine antibacterial activity of natural products. *Braz J Microbiol*;38:369-80.
19. Palombo, E. A. (2009) "Traditional Medicinal Plant Extracts and Natural Products with Activity against Oral Bacteria: Potential Application in the Prevention and Treatment of Oral Diseases," *Evidence-Based Complementary and Alternative Medicine*. 2011:1-25
20. Prabu GR, Gnanamani A, Sadulla S. (2006) Guaijaverin a plant flavonoid as potential antiplaque agent against *Streptococcus mutans*. *J Appl Microbiol*;101:487-95.
21. Gómez PAM, Mendizábal MFR, Poma RDC, Cifuentes TVR, Quispe FMM, Torres DJM, et al. Antibacterial and antiadhesion effects of *Psidium guajava* fractions on a multispecies biofilm associated with periodontitis. *Pesqui Bras Odontopediatria Clín Integr*. 2022; 22:e210080. <https://doi.org/10.1590/pboci.2022.028>

Table 1: isolates Name

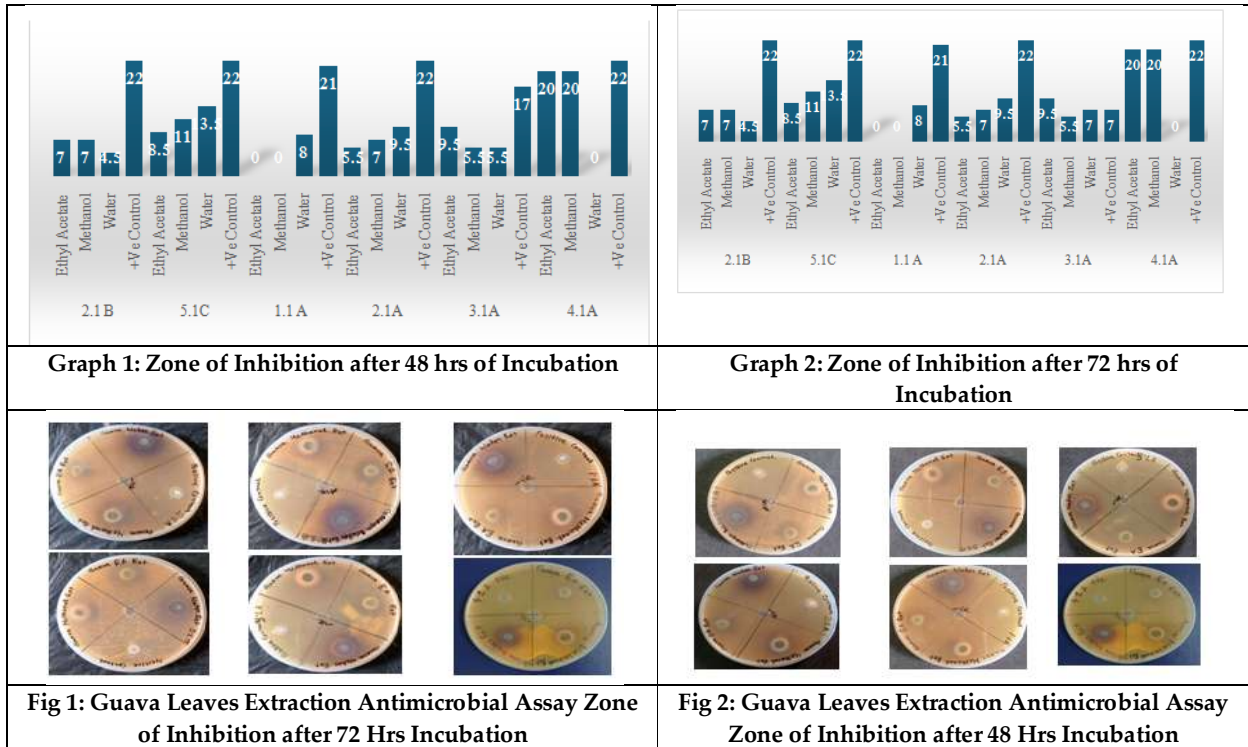
	Isolates	Identified as per Chemical Reactions
1	1.1A	<i>Klebsiella pneumoniae</i> subspecies ozaenae
2	2.1 A	<i>Klebsiella terrigena</i>
3	2.1 B	<i>Proteus myxofaciens</i>
4	3.1 A	<i>Proteus mirabilis</i>





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5	4.1 A	<i>Klebsiella terrigena</i>
6	5.1 C	<i>Escherichia coli</i> , inactive





Formulation and Organoleptic Evaluation of Mukhwaas As Functional Food

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ABSTRACT

Low intake of essential nutrients plays chief role in the beginning and progression of Non communicable diseases (NCDs), malnutrition and hidden hunger. The administration of nutrient dense food will limit the injury caused by its deficiency. The current study was conducted in this context with the overarching goal of creating a Mukhwaas that is richer in nutrients to maximise health. Acceptability of the mukhwaas was assessed by sensory evaluation and nutrient composition analysis was carried out by using standard methods. Sensory evaluation was assessed by composite score rating and hedonic scale where 40 panellists were administered one serving of the mukhwaas. The mukhwaas was developed using garden cress seeds, fennel seeds, coriander seeds, carom seeds, crystal sugar, liquorice root powder, clove and cardamom as base components. The nutritive value of accepted mukhwaas was 13.60 g of fat, 16.40 g of protein, 58.30 g of carbohydrates, 4.98 g of fibre, and 421 kcal of calories, 10.80 mg of iron, 359.5 mg of calcium, 238 mg of magnesium, 2.44 mg of zinc, and 1.21 mg of phosphorus per 100 g. The sensory evaluation revealed that functional food namely raw garden cress seeds powder incorporated at the level 40 g per 100 g was acceptable. The mukhwaas contained significant amounts of micronutrients and macronutrients, especially protein, iron, calcium. This study conclude that *Mukhwaas* was affordable, convenient and nutritious food which can be consumed at home, on the go, in workplaces and as a mouth freshener after or before meal. Thus, mukhwaas was functional food formulated in kitchen. It may assist to meet the demands of the "at risk" population and slow down the spread of NCDs.

Keywords: Mukhwaas, Garden Cress seeds, Fennel seeds, Product development, Sensory evaluation.





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INTRODUCTION

Non-communicable diseases (NCDs), which account for 74% of global fatalities today, include heart disease, stroke, cancer, diabetes, and chronic obstructive pulmonary disease. Seventy percent of all deaths in low- and middle-income countries (LMICs) are caused by NCDs. In 2019 [1], overweight and obesity contributed to 160 million disability-adjusted life years (DALYs) [2]. Diet-related NCDs like cardiovascular diseases (CVDs), diabetes, and kidney diseases caused by diabetes are among the top NCDs contributors to global annual deaths (17.9 and 2 million respectively) in 2019 [3]. Due to unique nutritional supply and bioactivity function, diverse plant-based diets and herbal medication manufacture are now being employed for the prevention of NCDs and communicable illnesses [4]. Eighty percent of the world's population uses traditional medicines, the majority of which are herbal concoctions, for basic healthcare requirements. Vast quantities of food and pharmaceuticals are made from medicinal plants [5].

In India, anaemia poses a serious threat to the health of mothers, young children, and teenage females. Anaemia is linked to a higher risk of maternal mortality, delayed mental and psychomotor development, and increased morbidity in addition to detrimental effects on physical well-being [6]. Garden cress (GC) seed or *Lepidium sativum* Linn is an herb of the family Cruciferae or Brassicaceae, has remarkable nutritional and medicinal value. Garden cress (*Lepidium sativum* L.) is a rapidly growing annual herb native to Egypt and western Asia that is now grown all over the world. Garden cress (GC) is also known as *Chandrasur* in local languages, and it is regarded as a significant medicinal crop in India. Garden cress may be grown and harvested throughout the year, with January, February, and November being the best months to sow in a mediterranean environment [7]. The garden cress seeds powder contain high amount of micro and macro nutrients such as, the seeds are high in calories (454 kcal) having 25 gm protein, 24 gm fat, 3 gm dietary fibre and 33 gm of carbohydrates per 100 gm and also has significant amount of minerals viz., 377 mg of calcium, 430 mg magnesium and 723 mg of phosphorous [8]. It is the very best iron containing plant supply ever known, approximately 100 mg/100g of iron is found in lawn cress seeds having a higher bioavailability [8,9]. GC seed is regarded as a "superfood" due to its high nutritional content, which is essential for enhancing the medicinal and nutritional value of formulated and blended food items. Applying numerous conventional processing techniques might make this better. Because of high nutritive value they are beneficial in treating different disease conditions such as, anti-inflammatory, hepatoprotective, fracture healing, antihypertensive, nephron protective, anti-cancer, anti-diabetic, treatment of anaemia, hypercholesterolemia, constipation.

It is supplemented in the diet of lactating women to increase the milk secretion during postnatal period and also recommended for the treatment of diarrhoea and dysentery. Ayurvedic practitioners prescribe seeds of GC for the treatment of bronchial asthmatic patients [7]. In India, it is customary to eat mukhwaas, a mouth freshener, after and between meals. Mukhwaas is a mouthwash or digestive aid that is used after a meal. It may be produced from a variety of seeds and nuts, although it is most commonly associated with fennel seeds, anise seeds, coconut, and sesame seeds. They have a sweet flavour and are extremely fragrant due to the presence of sugar and the addition of different essential oils. [10] report that the seeds can be savoury, sugar-coated, and vividly coloured. In modern diets, mouth fresheners include sugar-coated chewing gums, which contribute little nutritional benefit. Mukhwaas, when carefully designed and prepared in accordance with organoleptic assessments, may be an extra source of macro and micronutrients while also serving as a mouth refresher and assist in digesting. Several research have proved the nutritious value of the components used in Indian mukhwaas [10]. *Foeniculum vulgare* (fennel seeds) are widely used as mukhwaas (mouth fresheners) throughout India. Phytochemical analysis of fennel seeds revealed the presence of various useful chemicals, including volatile compounds, flavonoids, phenolic compounds, fatty acids, and amino acids [10]. Coriander seeds (*Coriandrum sativum* L.) are an annual plant that belongs to the Apiaceae family. The seeds are high in iron, zinc, copper, and vital minerals, which can help lower bad cholesterol and increase good cholesterol. Coriander seeds have antioxidant properties due to their inherent phenolic content [11]. This study aims to develop a mukhwaas from raw garden cress seeds powder (*Lepidium sativum* L.).





MATERIAL AND METHODS

The formulation of powdered mukhwaas was done considering the increase in essential nutrients requirement without increasing the expenses and suitable for all age group except pregnant women. Raw garden cress seed and other ingredients which used for developing a food product were procured from local grocery market of urban Vadodara. The seeds were then cleaned, graded and stored in jar till further use. It was ensured prior that the developed food product was nutritious, easy to prepare, palatable and inexpensive.

Development and standardization of mukhwaas

The garden cress seed were subjected to grinding and ground coarsely. The standard sample (T0) for 100g of product fennel seeds 40g, coriander seeds 30g, crystal sugar 10g, liquorice root powder 10g, carom seeds 3.3g, clove 3.3g and cardamom 3.4g were added. The mixture was grinded for 3-4 minutes. The mukhwaas were then mixed. The variant sample (T1) for 100g of product fennel seeds 30g, coriander seeds 10g, crystal sugar 10g, liquorice root powder 5g, carom seeds 1.7g, clove 1.6g and cardamom 1.7g were added. The mixture was grinded for 3-4 minutes and then ground garden cress seeds powder 40g were added and mixed. The variant sample (T2) for 100g of product fennel seeds 10g, coriander seeds 5g, crystal sugar 2g, liquorice root powder 2g, carom seeds 0.3g, clove 0.2g and cardamom 0.5g were added. The mixture was grinded for 3-4 minutes and then ground garden cress seeds powder 80g were added and mixed (Table 1 and Figure 1). This ratio of garden cress seeds powder was finalized from previous pilot trials with different variations (up to 0% to 80%) and because of the resulting in strong taste of garden cress seeds 40% were selected for analysis. Also, the reason for selection of 40 % incorporating was acute toxicity experiments the experiment by Malar et.al, (2017) on garden cress seeds found no deaths in rats at doses up to 1 g/kg body weight [12]. The chief reason that as per the recommended dietary allowance 2024 (RDA2024) the daily intake of iron for female children, adolescence and adult is 15 mg/d, 30 mg/d and 29 mg/d respectively and for male children, adolescence and adult is 15 mg/d, 22 mg/d and 19 mg/d respectively [13].

Costing of mukhwaas

The sample (T1) and sample (T2) of Mukhwaas combination contained garden cress seeds, fennel seeds, coriander seeds, crystal sugar, clove, carom seeds, cardamom and licorice root. Overall, the cost of licorice root, cardamom and clove was maximum among all ingredients used. An overall cost of Rs. 30.1 per 100 gm and Rs. 21.9 per 100 gm with including packaging cost respectively.

Packaging of product

Since the surface area of the particles get increased due to powdering, chances of moisture absorption and loss of flavour will be much more, therefore deterioration is fast in such products. Moreover, these products are intended for distant transportation and are sold in different markets as popular both in internal and export market, needs both additional protections. That's why the packaging of such type of product in LDPE and PP Bags are better to use They gives protection against moisture [14]. The product of garden cress seed powder *Mukhwaas* were packed in LDPE and PP bags (Figure 2)

Sensory evaluation

The jury consisted of 40 panellists (20 semi trained and 20 untrained) each, who conducted sensory evaluation of the developed mukhwaas on hedonic scale [15] and composite scoring test [16]. The panellists were in the range of 18-35 years. The panellists constituted of UG-PG students and professors of Parul university, Vadodara. The panel member was subjected to measure the palatability effect of mukhwaas on "like extremely" to "dislike extremely" range of the nine-point hedonic rating scale. The former response comprised a score of 9 whereas the latter carried a score of 1. Along with this, a composite rating score is termed as the 7-point composite rating score applied to ascertain the most suitable variant characterized from the specific organoleptic attributes namely; taste, appearance, odour, texture, absence of defects, suitability of serving size and overall acceptability. Absence of defects is referred to the suitable with other ingredients, appropriateness in consistency, inexistence of any bad odour and flavour, lack of



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non-edible stuff (as husk/chaff, grit, worms, weevils, plastic films, dirt, and hair), etc. It's not describing appearance here as appearance has been put under a separate attribute category for score determination.

Proximate nutritional analysis

The Proximate nutritional analysis of Mukhwaas was performed at Shree Analytical Testing and Research Laboratory (NABL Accredited Laboratory TC – 10630) located at Maharashtra. A standard approach was used to calculate calories, protein, carbohydrate, fat, fiber, calcium, magnesium, potassium, zinc, sodium, iron, and phosphorous (FASSAI manual). The analysis of protein was performed by using Kjeldahl method. Fat was estimated by the Soxhlet extraction method in which fat dissolved in solvent of petroleum ether.

Statistical analysis

The statistical analysis was carried out using the MS office16s [excel]. Results obtained were expressed as mean \pm standard deviation values for all three garden cress seeds food formulations. The analysis of variance ANOVA test were used at ($p < 0.05$) significance level.

RESULT

The nutrient analysis of the raw garden cress seeds per 100 g denoted that energy content was 454 kcal, 25 gm protein, 24 gm fat, 3 gm dietary fibre and 33gm of carbohydrates, 377 mg of calcium, 430 mg magnesium and 723 mg of phosphorous, niacin 14.3 mg, riboflavin 0.61 mg, thiamine 0.59 mg and 100 mg of iron [8].

Nutrient and proximate analysis formulated product

Nutrient analysis was conducted for the most acceptable sample of mukhwaas. The test result selected sample was 100 g of mukhwaas which incorporated with 40 g of garden cress seeds powder. According to nutrient analysis, the raw powdered garden cress seeds included product has 13.60 g of fat, 16.40 g of protein, 58.30 g of carbohydrates, 4.98 g of fiber, and 421 kcal of calories per 100 g. The product's mineral content was likewise high. 10.80 mg of iron, 359.5 mg of calcium, 238 mg of magnesium, 2.44 mg of zinc, and 1.21 mg of phosphorus are present per 100g (Table 2). However, Nambiar and Ansari (2021) reported that Mix seeds mukhwaas prepared with 15g of garden cress seeds had 476.91 kcal/100g calories, 20.34 g/100g protein, 31.51 g/100g fat, 27.24 g/100g carbs, 539.49 mg/100g calcium, and 11.45 mg/100g iron which were higher to that of results found out in the present study, which may be due to difference in other ingredients utilized for preparation of the product [17]. In another study conducted by R Gupta (2023) reported that *Namakpare* prepared with 20 percent of germinated garden cress seeds powder had 3.54 g of ash, 23.20g of fat, 2.20g of fiber, 11.45 g of protein, 20.85mg of iron 91.79 mg of calcium, 239.86 mg of phosphorus in which protein and calcium were lower and iron and fat were higher to that of result found out in the present study, which may be due to difference in other ingredients and preparation method is utilized. Also, because of germinated garden cress seeds powder was used in the preparation [18].

Thereafter the next phase of sensory analysis was conducted on the two developed samples of mukhwaas, which confirmed that both samples had well acceptability scores. Amongst them, the first sample (T1) was at the highest acceptable score based on the nine-point hedonic scale. The attributes in totality and not the individual attribute have been combined to arrive at the judgment of the best mukhwaas out of the two. The mean hedonic score of sample T1 was of 5.71 ± 2.31 (Table 3). Organoleptic attributes based on 100 -point composite scoring test revealed the first sample T1 to be at the highest position of acceptability with the total score 74.97 than sample 2 with the score of 61.9 which is insignificant at ($p < 0.05$). The total score is concerned, based on the taste, Appearance, odour, texture, absence of defects, suitability of serving and overall acceptability. The taste attribute of *mukhwaas* was non-significant at ($p < 0.05$), sample (T1) scored 13.7 ± 4.58 was more acceptable. Sample (T2) were less acceptable. The appearance of samples was accepted for having a pleasant yellowish green colour which was more suitable. The highest score for appearance was of the sample (T1) with 7.85 ± 1.57 and the sample (T2) scored 7.02 ± 2.09 shows least acceptable which is significant at ($p < 0.05$) level. The odour was non-significant at ($p < 0.05$), presence of desirable odour was



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detected with the decreasing of garden cress seeds levels. Sample (T1) secured the top position for odour with a score of 7.77 ± 1.68 and the sample (T2) scored 6.6 ± 2.02 was least accepted. The texture scores were significant at ($p < 0.05$), was observed with low level of garden cress seeds in the *mukhwaas* samples. The sample (T1) had the maximum score of 11.6 ± 3.42 for this attribute and sample (T2) scored 11.4 ± 3.13 was least acceptable. Absence of defects attribute of *mukhwaas* displayed a non-significant at ($p < 0.05$) with decreasing the garden cress seeds substitution levels. Sample (T1) scored 8.07 ± 1.92 which was more acceptable and the sample (T2) scored 6.05 ± 3.20 was less acceptable. Suitability of serving paved for a significant at ($p < 0.05$). Suitability of serving is the ease with which the given amount of *mukhwaas* can be entirely consumed at a particular time it was acceptable Sample (T1) scored 11.3 ± 3.49 was more acceptable. In terms of overall acceptability non-significant at ($p < 0.05$), the score of sample (T1) was 14.6 ± 3.89 it was more acceptable and sample (T2) scored 11 ± 5 was less acceptable. The (T1) sample significantly fared superiorly than sample (T2) (Figure 3). However, in the study by Jain, Grover and Grewal (2016) reported that ready to eat supplementary food *panjiri* was prepared by incorporating roasted garden cress seeds powder at 5%, 10% and 15% and sensory evaluation is done by 9 point hedonic scale (watts *et al.*, 1989)[20] was used it shows non-significant differences at level of ($p < 0.05$) in appearance at 5% and 10% and shows significant difference at 15% and it obtained a least acceptability the present result found that raw garden cress seeds powder with incorporated at 40% was significant at ($p < 0.05$) level and acceptable this may be because of different preparation method and ingredients use to prepared a *panjiri*[19]. In another study conducted by Sharma (2015) investigated that incorporation of germinated garden cress seeds at 25% in *bhujiawas* significant at level of ($p < 0.05$) in overall acceptability the present study outcomes found that 40% of incorporation of raw garden cress seeds were insignificant at the level of ($p < 0.05$) it may be because of different sensory score card is used and also, because of different preparation method was used [20]. In another study by Hasan and Mohamed (2019) experimented that roasted garden cress seeds flour used for developing water biscuits was insignificant differences in between control group and treated samples in overall acceptability. Similarly, in the present study treated sample 1 and sample 2 was insignificant in overall acceptability with standard sample[22]. A characteristic that we observed while conducting our research is that, whereas the panellists were all professors and students at Parul University in Gujarat, some of them were not from Gujarat; instead, some of them were from Maharashtra, South India, Rajasthan, Bhutan or Nepal, and they have different sensory attributes. Like a South Indians, prefer sample 2, which has 80% incorporated with powdered garden cress seeds and tastes and odour is like spices. Some panellists, who are originally from Nepal or Bhutan, even dislike the idea of *mukhwaas* in powder form and the intense flavour of garden cress seeds.

CONCLUSION

There is a growing consumer need for food items that are delicious, reliable, feasible, and nutritious. As a result, nutrition became an extra component in the process of creating food products. In the process of developing new food products, a number of unusual foods have been investigated, examined, processed, and utilised. One such food that is loaded with health-promoting phytochemicals and nutrients is garden cress (*Lepidium sativum* L.) Its excellent nutritional properties enable it to combat both life-threatening illnesses and hidden hunger and malnutrition. However, its disagreeable taste might work against it in nutritional uses. Thus, based on our study. The sensory evaluation revealed that functional food namely raw garden cress seeds powder incorporated at the level 40 g per 100 g was acceptable. A research reported that utilization of garden cress seeds incorporation in a food product is up to 10-25 % is acceptable which might be due to the processing technique of garden cress seeds are different. The *mukhwaas* contained significant amounts of micronutrients and macronutrients, especially protein, iron, calcium. This conclude that *Mukhwaas* was affordable, convenient and nutritious food which can be consumed at home, on the go, in workplaces and as a mouth freshener after or before meal. Thus, *mukhwaas* was kitchen formulated functional food which may help to cater to the needs of "at risk" population and thereby retard the epidemic of NCDs.

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Conflict of Interest

There is no conflict of interest between author regarding the paper publishing.

REFERENCES

1. WHO. (2022). Noncommunicable diseases. <https://www.who.int/news-room/fact-sheets/detail/noncommunicable-diseases>
2. IHME (Institute for Health Metrics and Evaluation). (2022). High body-mass index -Level 2 risk. https://www.healthdata.org/results/gbd_summaries/2019/high-body-mass-index-level-2-risk
3. WHO. (2011). Global Status Report on Noncommunicable Diseases 2010.
4. Azene M, Habte K, Tkuwab H. Nutritional, health benefits and toxicity of underutilized garden cress seeds and its functional food products: a review. *Food Production, Processing and Nutrition*. 2022 Dec;4(1):1-3.
5. Alqahtani, F. Y., Aleanizy, F. S., Mahmoud, A. Z., Farshori, N. N., Alfaraj, R., Al-Sheddi, E. S., & Alsarra, I. A. (2019). Chemical composition and antimicrobial, antioxidant, and anti-inflammatory activities of *Lepidium sativum* seed oil. *Saudi Journal of Biological Sciences*, 26(5), 1089–1092. <https://doi.org/10.1016/j.sjbs.2018.05.007>.
6. Ministry of Health and Family Welfare. Comprehensive National Nutrition Survey; 2019. Available at https://www.popcouncil.org/uploads/pdfs/2019RH_CNNS_report.pdf. (Last accessed on 1 December 2020)
7. Singh CS, Paswan VK. The potential of garden cress (*Lepidium sativum* L.) seeds for development of functional foods. *Advances in Seed Biology*. 2017 Dec 6.
8. C. Gopalan, B.V. Rama Sastri, S.C. Balasubramanian, B.S. Narasinga Rao, Y. G. Desothale, K. C. Pant. Nutritive value of Indian foods. Hyderabad: National Institute of Nutrition (ICMR) at their offset press;1989(reprinted2021). p. 52, 63, 71.
9. Chand Y, Srivastav DN, Seth AK, Vipin S, Balaraman R, Tejas KG. *In vivo* antioxidant potential of *Lepidium sativum* L. seeds in albino rats using cisplatin induced nephrotoxicity. *International Journal of Phytomedicine*. 2010; 2:292-298.
10. Shamkant B. Badgujar, Vainav V. Patel, Atmaram H. Bandivdekar, "Foeniculum vulgare Mill: A Review of Its Botany, Phytochemistry, Pharmacology, Contemporary Application, and Toxicology", *BioMed Research International*, vol. 2014, Article ID 842674, 32 pages, 2014. <https://doi.org/10.1155/2014/842674>
11. Shahrajabian, M.H.; Sun, W. Five Important Seeds in Traditional Medicine, and Pharmacological Benefits. *Seeds* 2023, 2, 290-308. <https://doi.org/10.3390/seeds2030022>
12. Malar, M. J., Vanmathi, J. S., & Chairman, K. (2017). Antidiabetic activity of different parts of the plant *lepidiumsativum* Linn. *Asian Journal of Applied Science and Technology*, 1(9), 135–141.
13. ICMR- National Institute of Nutrition (2024) https://www.nin.res.in/RDA_short_Report_2024.html
14. Chapter in a book: John P. Jacob. Packaging of different products. In: A handbook on food packaging. New Delhi: Daya publishing house;2017. p. 121- 123.
15. M. Swaminathan, Food Science and Experimental Foods (Ganesh and Company, Madras, 1995), p. 293
16. V.K. Joshi, Sensory science (Agrotech Publishing Academy, Udaipur, 2006), pp. 266–268.
17. Nambiar, Vanisha & Ansari, Sabat. (2021). 'MUKHWAS' MIX -Indian Mouth Fresheners and their potential role in reducing micronutrient malnutrition. 7. 95-101. 10.36537/IJAHS/7.7-12/95-101.
18. Gupta R. Formulation and nutritional quality evaluation of namakpare supplemented with garden cress (*Lepidium sativum* L.) seeds. *Himachal Journal of Agricultural Research*. 2023 Jun 1;49(1):113-9.
19. Jain T, Grover K, Grewal IS. Development and sensory evaluation of ready to eat supplementary food using garden cress (*Lepidium sativum*) seeds. *Journal of Applied and Natural Science*. 2016 Sep 1;8(3):1501-6.
20. Watts, B.M., Ylimaki, G.L., Jeffery, L.E. and Elias, L.G. (1989). Basic sensory methods for food evaluation. IDRC-277e. The International Development research Centre, Ottawa, Canada.
21. Sharma M. Formulation and sensory evaluation of food products developed by incorporating germinated garden cress seeds (*Lepidium sativum* L.). *International Journal of Sciences: Basic and Applied Research*. 2015;23(1):181-8.
22. Hassan MA, Abdel-Rahman AM. The influence of dry roasting process on chemical and nutritional properties of garden cress seeds flour. *Int. Adv. Res. J. Sci. Eng. Technol*. 2019;6(11).





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Table 1: The amount of ingredients added in product (mukhwaas)

Ingredients	Standard sample	T-1*	T-2*
Garden cress seeds	-	40gm	80gm
Fennel seeds	40gm	30gm	10gm
Coriander seeds	30gm	10gm	5gm
Crystal sugar	10gm	10gm	2gm
Clove	3.3gm	1.6gm	0.2gm
Carom seeds	3.3gm	1.7gm	0.3gm
Cardamon	3.4gm	1.7gm	0.5gm
Licorice root powder	10gm	5gm	2gm

T-1 was recipe one (40%), T-2 is recipe two (80%).

Table 2: Nutrient profile test report

Sr. No.	Parameters	Result / 100 gm	Unit	Method
1	Energy	421 kcal	Kcal / 100gm	FSSAI manual
2	Protein	16.40 gm	g / 100 gm	FSSAI manual
3	Fat	13.60 gm	g / 100 gm	FSSAI manual
4	Carbohydrate	58.30 gm	g / 100 gm	FSSAI manual
5	Fiber	4.98 gm	g / 100 gm	FSSAI manual
6	Calcium	359.5 mg	mg / 100gm	FSSAI manual
7	Magnesium	238 mg	mg / 100gm	FSSAI manual
8	Potassium	631 mg	mg / 100gm	FSSAI manual
9	Zinc	2.44 mg	mg / 100gm	FSSAI manual
10	Sodium	230 mg	mg / 100gm	FSSAI manual
11	Iron	10.80 mg	mg / 100gm	FSSAI manual
12	Phosphorous	1.21 mg	mg / 100gm	FSSAI manual

Table 3: Nutritional composition of mukhwaas with mean hedonic scale

Variations	Varied garden cress seeds amount in base in grams	Hedonic score (semi trained)
Sample I (T1)	40%	5.71 ± 2.31
Sample II (T2)	80%	4.44 ± 2.16

Table 4: Mean composite scores of mukhwaas variation (N=40) by panelists

Variations	Taste (20)	Appearance (10)	Odour (10)	Texture (15)	Absence of defect (10)	Suitability of serving (15)	Overall acceptability (20)	Total scores (100)
Sample T1	13.7 ± 4.58	7.85 ± 1.57	7.77 ± 1.68	11.6 ± 3.42	8.07 ± 1.92	11.3 ± 3.49	14.6 ± 3.89	74.9 ± 15.6
Sample T2	10.1 ± 5.02	7.02 ± 2.09	6.6 ± 2.02	11.4 ± 3.13	6.05 ± 3.20	9.67 ± 3.78	11.0 ± 5.05	61.9 ± 19.7
ANOVA	0.0013 ^{NS}	0.0526*	0.0066 ^{NS}	0.7631*	0.0011 ^{NS}	0.0524*	0.0009 ^{NS}	0.000 ^{NS}

* Significance level at P value <0.05, NS- non-significant





Figure 1: Three variants of product



Figure 2: Packaging of product

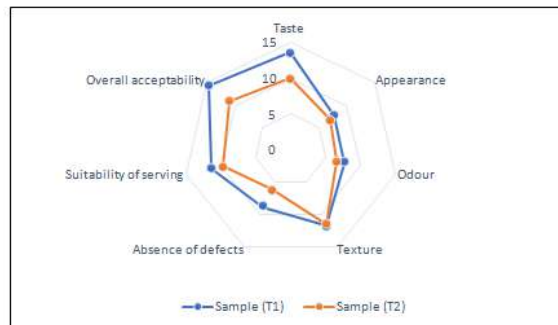


Figure 3: Score card of mean composite scores of overall formulated mukhwaas variations assessed by (N=40) panellists.





A Common Fixed -Point Theorems in Complex Valued Dislocated Metric Spaces

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ABSTRACT

In this paper we have established some common fixed-point theorems in complex valued dislocated metric spaces. In a paper Ozgur Ege and Ismet Karaca established some fixed-point results in complex valued dislocated metric spaces for a single self-map. By inspiring the result of Ozgur and Karaca we proved a generalized theorem for four mapping by utilizing weakly compatibility. Carrying forward our study we also dealt with double controlled dislocated metric spaces in the complex valued sense and proved a common fixed point theorem. Towards the end we have also given an example to verify the applicability of our results.

Keywords: Dislocated metric, weakly compatible maps, common fixed point, complex valued metric space.

American Mathematical Subject Classification(2000): 47H10, 54H25.

INTRODUCTION

In 2000, Hitzler and Seda[1] developed the concept of dislocated metric space by taking the idea that the self-distance of a point need not to be zero necessarily. They also generalized the Banach contraction principle in this structure. Zeyada et al.[2] introduced the notion of complete dislocated quasi-metric space and generalized the result





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of Hitzler in dislocated quasi-metric space. Further Aage and Salunke[3] proved some results regarding fixed points for a map and pair of maps in dislocated metric space. Moreover, by using the notion of weakly compatibility of mappings Jha and Panthi[4], Prudhvi[5] established some common fixed-point theorem for two pairs of mappings in dislocated metric space. On other hand, Azam et al. [6] defined the notion of complex valued metric spaces in which the distance functions map into the complex numbers. They also proved common fixed-point results in complex valued metric spaces which is further extended by Sintunavarat et al. [7]. In 2018, Ozgur Ege and Ismet Karacha[8] introduced the complex valued dislocated metric spaces and proved Banach, Kanan and Chatterjea type fixed point theorems in this new space. In this paper we prove a common fixed-point theorem for two pairs of weakly compatible maps in complex valued dislocated metric space. Further we studied controlled and double controlled type metric spaces in [9,10,11,12]. We also constructed a new theorem in complex valued double controlled dislocated metric spaces.

PRELIMINARIES

In this section, we will discuss some basic definitions and results which are useful in throughout the paper.

Definition 2.1[8] Let \mathbb{C} be the set of complex numbers and $z_1, z_2 \in \mathbb{C}$.

Define a partial order \lesssim on \mathbb{C} as: $z_1 \lesssim z_2$ iff $Re(z_1) \leq Re(z_2), Im(z_1) \leq Im(z_2)$. It follows that $z_1 \lesssim z_2$ if one of the following conditions hold:

1. $Re(z_1) = Re(z_2)$ and $Im(z_1) = Im(z_2)$
2. $Re(z_1) < Re(z_2)$ and $Im(z_1) = Im(z_2)$
3. $Re(z_1) = Re(z_2)$ and $Im(z_1) < Im(z_2)$
4. $Re(z_1) < Re(z_2)$ and $Im(z_1) < Im(z_2)$

We write $z_1 \approx z_2$ if $z_1 \neq z_2$ and one of (ii) and (iii) is satisfied and we write $z_1 < z_2$ if only (iv) is satisfied.

Here we note the following holds trivially:

1. If $0 \lesssim z_1 \lesssim z_2$ then $|z_1| \leq |z_2|$;
2. If $0 \lesssim z_1 \approx z_2$ then $|z_1| < |z_2|$;
3. If $z_1 < z_2$ and $z_2 < z_3$ then $z_1 < z_3$;
4. If $a, b \in \mathbb{R}$ and $a \leq b$ then $az \lesssim bz$ for all $z \in \mathbb{C}$;
5. If $a, b \in \mathbb{R}$ and $0 \leq a \leq b$ and $z_1 \lesssim z_2$ implies $az_1 \lesssim bz_2$.

Definition 2.2 [8] Let X be a nonempty set and $d: X \times X \rightarrow \mathbb{C}$ be a function satisfying the following conditions:

$$d(x, y) = d(y, x);$$

$$d(x, y) = d(y, x) = 0 \text{ implies } x = y.$$

$$d(x, y) \lesssim d(x, z) + d(z, y) \text{ for all } x, y, z \in X.$$

Then d is called complex valued dislocated metric on X and (X, d) is called complex valued dislocated metric space (or simply complex valued d -metric space). Now throughout this paper (X, d) stands for complex valued dislocated metric space.

Example 2.1[8] Let $d: X \times X \rightarrow \mathbb{C}$ be defined by

$$d(x, y) = \max\{x, y\} \text{ where } X = \mathbb{C} \text{ then, } (X, d) \text{ is a complex valued dislocated metric space. (or simply complex valued } d\text{-metric space).}$$

Definition 2.3[8] Let (X, d) be a complex valued dislocated metric space, $\{x_n\}$ be a sequence in X and $x \in X$.

1. The sequence $\{x_n\}$ is said to be complex valued d -convergent in (X, d) and converges to x , if for every $\epsilon > 0$ there exists $n_0 \in \mathbb{N}$ such that $d(x_n, x) < \epsilon$ for all $n > n_0$ and is denoted by $x_n \rightarrow x$ as $n \rightarrow \infty$.
2. The sequence $\{j_n\}$ is called complex valued Cauchy sequence in (X, d) if $\lim_{n \rightarrow \infty} d(x_n, x_{n+p}) = 0$ for all $p > 0$.
3. If every complex valued Cauchy sequence in X converges to some $x \in X$, then (X, d) is said to be a complex valued complete dislocated metric space.





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Lemma 2.1 [8] Let (X, d) be a complex valued dislocated metric space and let $\{x_n\}$ be a sequence in X . Then $\{x_n\}$ converges to x if and only if $|d(x_n, x)| \rightarrow 0$ as $n \rightarrow \infty$.

Definition 2.4 [8] Let (X, d) be a complex valued dislocated metric space. A mapping $T: X \rightarrow X$ is called contraction if there exists $0 \leq \lambda < 1$ such that $d(Tx, Ty) \lesssim \lambda d(x, y)$ for all $x, y \in X$. converges to x if and only if $|d(x_n, x)| \rightarrow 0$ as $n \rightarrow \infty$.

Lemma 2.2[8] Let (X, d) be a complex valued dislocated metric space and let $\{x_n\}$ be a sequence in X . Then $\{x_n\}$ is a complex valued Cauchy sequence if and only if $|d(x_n, x_{n+m})| \rightarrow 0$ as $n \rightarrow \infty$.

Lemma 2.3 Limit of a sequence $\{x_n\}$ in a complex valued dislocated metric space is unique.

Proof. Let x_1 and x_2 be limits of the sequence $\{x_n\}$ in a complex valued dislocated metric space (X, d) , then

$$\begin{aligned} d(x_1, x_2) &\lesssim d(x_1, x_n) + d(x_n, x_2) \\ \Rightarrow |d(x_1, x_2)| &\leq |d(x_1, x_n) + d(x_n, x_2)| = |d(x_1, x_n)| + |d(x_n, x_2)| \\ \Rightarrow |d(x_1, x_2)| &\leq |d(x_1, x_n)| + |d(x_n, x_2)| \rightarrow 0 \text{ as } n \rightarrow \infty. \\ \Rightarrow d(x_1, x_2) &= 0, \text{ it follows that } x_1 = x_2. \end{aligned}$$

Definition 2.5 Let two self-maps S and T of a complex valued dislocated metric space (X, d) . The pair (S, T) is said to be weakly compatible if S and T commute at their coincident point; i.e. $TSx = STx$ whenever $Sx = Tx$ for all $x \in X$.

MAIN RESULTS

Theorem 3.1 Let (X, d) be a complete complex valued dislocated metric space and

$A, B, S, T: X \rightarrow X$ be continuous mappings satisfying,

$$T(X) \subseteq A(X), S(X) \subseteq B(X)$$

The pairs (S, A) and (T, B) are weakly compatible and

$$d(Sx, Ty) \lesssim \alpha[d(Ax, Sx) + d(By, Ty)] + \beta[d(Ax, Ty) + d(Bx, Sy)] + \gamma d(Ax, By)$$

for all $x, y \in X$ where $\alpha, \beta, \gamma \geq 0, \alpha + 2\beta + \frac{\gamma}{2} < \frac{1}{2}$. Then A, B, S and T have a unique common fixed point.

Proof. Using condition (3.1.1), we define sequences $\{x_n\}$ and $\{y_n\}$ in X by the rule

$$y_{2n} = Bx_{2n+1} = Sx_{2n} \text{ and } y_{2n+1} = Ax_{2n+2} = Tx_{2n+1}, \quad n = 0, 1, 2, \dots$$

If $y_{2n} = y_{2n+1}$ for some n , then $Bx_{2n+1} = Tx_{2n+1}$. Therefore x_{2n+1} is a coincidence point of B and T . Also, if $y_{2n+1} = y_{2n+2}$ for some n , then $x_{2n+2} = Sx_{2n+2}$. Hence x_{2n+2} is a coincidence point of S and A . Assume that $y_{2n} \neq y_{2n+1}$ for all n . Then, we have

$$\begin{aligned} d(y_{2n}, y_{2n+1}) &= d(Sx_{2n}, Tx_{2n+1}) \\ &\lesssim \alpha[d(Ax_{2n}, Sx_{2n}) + d(Bx_{2n+1}, Tx_{2n+1})] + \beta[d(Ax_{2n}, Tx_{2n+1}) + d(Bx_{2n+1}, Sx_{2n})] \\ &\quad + \gamma d(Ax_{2n}, Bx_{2n+1})d(y_{2n}, y_{2n+1}) \\ &\lesssim \alpha[d(y_{2n-1}, y_{2n}) + d(y_{2n}, y_{2n+1})] + \beta[d(y_{2n-1}, y_{2n+1}) + d(y_{2n}, y_{2n})] \\ &\quad + \gamma[d(y_{2n-1}, y_{2n})]d(y_{2n}, y_{2n+1}) \\ &\lesssim \alpha[d(y_{2n-1}, y_{2n}) + d(y_{2n}, y_{2n+1})] + \beta[d(y_{2n-1}, y_{2n}) + d(y_{2n}, y_{2n+1}) + d(y_{2n}, y_{2n+1})] \\ &\quad + d(y_{2n+1}, y_{2n}) + \gamma[d(y_{2n-1}, y_{2n})] \end{aligned}$$

$$d(y_{2n}, y_{2n+1}) \lesssim (\alpha + \beta + \gamma)d(y_{2n-1}, y_{2n}) + (\alpha + 3\beta)d(y_{2n}, y_{2n+1})$$

$$d(y_{2n}, y_{2n+1}) \lesssim \left(\frac{\alpha + \beta + \gamma}{1 - \alpha - 3\beta}\right) d(y_{2n-1}, y_{2n}). \text{ Thus we have,}$$

$$|d(y_{2n}, y_{2n+1})| \leq \left(\frac{\alpha + \beta + \gamma}{1 - \alpha - 3\beta}\right) |d(y_{2n-1}, y_{2n})|.$$

Similarly,

$$d(y_{2n+1}, y_{2n+2}) \lesssim \alpha[d(y_{2n}, y_{2n+1}) + d(y_{2n+1}, y_{2n+2})] + \beta[d(y_{2n}, y_{2n+2}) + d(y_{2n+1}, y_{2n+1})] + \gamma[d(y_{2n}, y_{2n+1})]$$

$$\begin{aligned} d(y_{2n+1}, y_{2n+2}) &\lesssim \alpha[d(y_{2n}, y_{2n+1}) + d(y_{2n+1}, y_{2n+2})] + \\ &\quad \beta[d(y_{2n}, y_{2n+1}) + d(y_{2n+1}, y_{2n+2}) + d(y_{2n+1}, y_{2n+2}) + d(y_{2n+2}, y_{2n+1})] \\ &\quad + \gamma[d(y_{2n}, y_{2n+1})]d(y_{2n+1}, y_{2n+2}) \lesssim (\alpha + \beta + \gamma)d(y_{2n}, y_{2n+1}) + (\alpha + 3\beta)d(y_{2n+1}, y_{2n+2}) \end{aligned}$$





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$d(y_{2n+1}, y_{2n+2}) \lesssim \left(\frac{\alpha+\beta+\gamma}{1-\alpha-3\beta}\right) d(y_{2n}, y_{2n+1})$. Thus we have,

$$|d(y_{2n+1}, y_{2n+2})| \leq \left(\frac{\alpha + \beta + \gamma}{1 - \alpha - 3\beta}\right) |d(y_{2n}, y_{2n+1})|.$$

In general

$$d(y_n, y_{n+1}) \lesssim \delta d(y_{n-1}, y_n) \lesssim \delta^2 d(y_{n-2}, y_{n-1}) \dots \lesssim \delta^n d(y_0, y_1)$$

where $\delta = \left(\frac{\alpha+\beta+\gamma}{1-\alpha-3\beta}\right) < 1$. Now for every integer $k > 0$, by triangular inequality $d(y_n, y_{n+k}) \lesssim d(y_n, y_{n+1}) +$

$$d(y_{n+1}, y_{n+2}) + \dots + d(y_{n+k-1}, y_{n+k})$$

$$\lesssim (\delta + \delta^2 + \dots + \delta^{k-1}) d(y_0, y_1) = \frac{\delta^n}{1 - \delta} d(y_0, y_1).$$

$$|d(y_n, y_{n+k})| \leq \frac{\delta^n}{1 - \delta} |d(y_0, y_1)|.$$

Since, $0 \leq \delta < 1$. Taking limits $n \rightarrow \infty$, then $|d(y_n, y_{n+k})| \rightarrow 0$. Hence, lemma 2.2 implies that $\{y_n\}$ is a Cauchy sequence in a complete dislocated metric space. So, there exist a point $z \in X$ such that $\{y_n\} \rightarrow z$. Therefore, the subsequences, $\{Sx_{2n}\} \rightarrow z, \{Bx_{2n+1}\} \rightarrow z, \{Tx_{2n+1}\} \rightarrow z$ and $\{Ax_{2n+2}\} \rightarrow z$.

Since, $T(X) \subseteq A(X)$, there exist a point $u \in X$ such that $z = Au$. So, $d(Su, z) = d(Su, Tx_{2n+1}) \lesssim \alpha[d(Au, Su) + d(Bx_{2n+1}, Tx_{2n+1})] + \beta[d(Au, Tx_{2n+1}) + d(Bx_{2n+1}, Su)] + \gamma d(Au, Bx_{2n+1})$. $d(Su, z) \lesssim \alpha[d(z, Su) + d(z, z)] + \beta[d(z, z) + d(z, Su)] + \gamma d(z, z)$. $d(Su, z) \lesssim (3\alpha + 3\beta + 2\gamma)d(z, Su) \Rightarrow |d(Su, z)| \leq (3\alpha + 3\beta + 2\gamma)|d(z, Su)|$

which is the contradiction, since $3\alpha + 3\beta + 2\gamma < 1$. So, we have $Su = Au = z$. Again, since $S(X) \subseteq B(X)$, there exist a point $v \in X$ such that $z = Bv$. We claim that $z = Tv$. If $z \neq Tv$, then $d(z, Tv) = d(Su, Tv) \lesssim \alpha[d(Au, Su) + d(Bv, Tv)] + \beta[d(Au, Tv) + d(Bv, Su)] + \gamma d(Au, Bv)$. $d(z, Tv) \lesssim \alpha[d(z, z) + d(z, Tv)] + \beta[d(z, Tv) + d(z, z)] + \gamma d(z, z)$. $d(z, Tv) \lesssim (3\alpha + 3\beta + 2\gamma)d(z, Tv) \Rightarrow |d(z, Tv)| \leq (3\alpha + 3\beta + 2\gamma)|d(z, Tv)|$.

which is the contradiction, since $3\alpha + 3\beta + 2\gamma < 1$. So, we get $z = Tv$. Hence we have $Su = Au = Tv = Bv = z$.

Since, the pair (S, A) are weakly compatible so by the definition $SAu = ASu \Rightarrow Sz = Az$. Now, we show that z is the fixed point of S . if $Sz \neq z$, then $d(Sz, z) = d(Sz, Tv) \lesssim \alpha[d(Az, Sz) + d(Bv, Tv)] + \beta[d(Az, Tv) + d(Bv, Sz)] + \gamma d(Az, Bv)$. $d(Sz, z) \lesssim \alpha[d(Sz, Sz) + d(z, z)] + \beta[d(Sz, z) + d(z, Sz)] + \gamma d(Sz, z)$. $d(Sz, z) \lesssim (4\alpha + 2\beta + \gamma)d(Sz, z) \Rightarrow |d(Sz, z)| \leq (4\alpha + 2\beta + \gamma)|d(Sz, z)|$.

which is the contradiction. So, we have $Sz = z$. This implies $Az = Sz = z$. Again, the pair (T, B) are weakly compatible so by the definition $TBv = BTv \Rightarrow Tz = Bz$. Now we show that z is the fixed point of T . if $Tz \neq z$, then $d(z, Tz) = d(Sz, Tz) \lesssim \alpha[d(Az, Sz) + d(Bz, Tz)] + \beta[d(Az, Tz) + d(Bz, Sz)] + \gamma d(Az, Bz)$. $d(z, Tz) \lesssim \alpha[d(z, z) + d(Tz, Tz)] + \beta[d(z, Tz) + d(Tz, z)] + \gamma d(z, Tz)$. $d(z, Tz) \lesssim (4\alpha + 2\beta + \gamma)d(z, Tz) \Rightarrow |d(z, Tz)| \leq (4\alpha + 2\beta + \gamma)|d(z, Tz)|$

which is contradiction So, we have $z = Tz$. Hence we have $Az = Bz = Sz = Tz = z$. This shows that z is the fixed point of the self mappings A, B, S and T .

Uniqueness

Let $u \neq v$ be two common fixed point of the mappings A, B, S and T . Then we have $d(u, v) = d(Su, Tv) \lesssim \alpha[d(Au, Su) + d(Bv, Tv)] + \beta[d(Au, Tv) + d(Bv, Su)] + \gamma d(Au, Bv)$. $d(u, v) \lesssim \alpha[d(u, u) + d(v, v)] + \beta[d(u, v) + d(v, u)] + \gamma d(u, v)$. $d(u, v) \lesssim (4\alpha + 2\beta + \gamma)d(u, v) \Rightarrow |d(u, v)| \leq (4\alpha + 2\beta + \gamma)|d(u, v)|$

which is the contradiction. This shows that $d(u, v) = 0$. Since, (X, d) is a dislocated metric space, so we have $u = v$. This proves the theorem. If we take a sequence $\{x_n\}$ defined by $x_n = T^n x_0$ and set $T = S, A = B = I$ and $\beta = \gamma = 0$ in theorem 3.1.1 then, we have the following result theorem 3.1 of O. Ege and I. Karaca as the corollary.

Corollary 3.1 Let (X, d) be complex valued complete dislocated metric space and $S: X \rightarrow X$ be a map. If there exists a constant $0 \leq \alpha < \frac{1}{2}$ and $d(Sx, Sy) \lesssim \alpha[d(x, Sx) + d(y, Sy)]$ for all $x, y \in X$, then S has a unique fixed point in X . This is the Kannan type fixed point theorem established by O. Ege et. al [8]. Again if we take $S = T, A = B = I$ and put $\alpha = \gamma = 0$ in theorem 3.1 we have the following result, theorem 3.10 of O. Ege and I. Karaca as the corollary.





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Corollary 3.2 Let (X, d) be complex valued complete dislocated metric space and $T: X \rightarrow X$ is continuous map satisfying $d(Tx, Ty) \lesssim \beta[d(x, Ty) + d(y, Tx)]$ where $0 \leq \beta < \frac{1}{4}$ and for all $x, y \in X$, then T has a unique fixed point in X . This is the Chatterjea fixed point theorem established by O. Ege et. al [8].

Example 3.1 Let (X, d) be complex valued dislocated metric space where $X = [0, 1]$ and $d: X \times X \rightarrow \mathbb{C}$ is defined by $d(x, y) = i|x + y|$. Define self maps A, B, S and $T.A(X) = \frac{x}{2}; T(X) = \frac{x}{3}; S(X) = \frac{3x}{4}; B(X) = x$

Clearly that $A(X) \subseteq T(X)$ and $B(X) \subseteq S(X)$.

We observe that $BT(0) = TB(0)$ when $B(0) = T(0)$ and $AS(0) = SA(0)$ when $A(0) = S(0)$. Hence the pair (A, S) and (B, T) are weakly compatible.

Now by condition (3.1.3) of theorem 3.1

$$i \left| \frac{3x}{4} + \frac{y}{3} \right| \lesssim \alpha \left[i \left| \frac{x}{2} + \frac{3x}{4} \right| + i \left| y + \frac{x}{3} \right| \right] + \beta \left[i \left| \frac{x}{2} + \frac{x}{3} \right| + i \left| y + \frac{3x}{4} \right| \right] + \gamma \left[i \left| \frac{x}{2} + y \right| \right]$$

$$\left| \frac{3x}{4} + \frac{y}{3} \right| \leq \alpha \left[\left| \frac{x}{2} + \frac{3x}{4} \right| + \left| y + \frac{x}{3} \right| \right] + \beta \left[\left| \frac{x}{2} + \frac{x}{3} \right| + \left| y + \frac{3x}{4} \right| \right] + \gamma \left[\left| \frac{x}{2} + y \right| \right]$$

at $x = 0$ and $y = 0$ the above inequality is obvious.

at $x = 0$ and $y = 1, \frac{1}{3} \leq \alpha(1) + \beta(1) + \gamma(1)$

at $x = 1$ and $y = 1, \frac{13}{12} \leq \alpha \left(\frac{31}{12} \right) + \beta \left(\frac{31}{12} \right) + \gamma \left(\frac{3}{2} \right)$.

Hence the inequality

$d(Sx, Ty) \lesssim \alpha[d(Ax, Sx) + d(By, Ty)] + \beta[d(Ax, Ty) + d(By, Sx)] + \gamma d(Ax, By)$ holds good for all $x, y \in X$ where $\alpha = \frac{1}{5}, \beta = \frac{1}{9}, \gamma = \frac{1}{7}, \alpha + 2\beta + \frac{\gamma}{2} < \frac{1}{2}$. Then A, B, S and T have a unique common fixed point.

Definition 3.1 [11] Let X be a non-empty set and $\wp, \ell: X \times X \rightarrow [1, \infty)$. Define a distance function on X as $d_{\mathbb{C}}: X \times X \rightarrow \mathbb{C}$ where \mathbb{C} the set of all complex numbers, satisfying the following conditions:

$D_1: \forall x, y \in X d_{\mathbb{C}}(x, y) = d_{\mathbb{C}}(y, x);$

$D_2: \forall x, y \in X d_{\mathbb{C}}(x, y) = d_{\mathbb{C}}(x, y) = 0$ implies $x = y$.

$D_3: \forall x, y, z \in X d_{\mathbb{C}}(x, y) \lesssim d_{\mathbb{C}}(x, z) + d_{\mathbb{C}}(z, y)$

$D_4: \forall j, k, l \in X d_{\mathbb{C}}(x, y) \lesssim \wp(x, z)d_{\mathbb{C}}(x, z) + \wp(z, y)d_{\mathbb{C}}(z, y)$

$D_5: \forall x, y, z \in X d_{\mathbb{C}}(x, y) \lesssim \wp(x, z)d_{\mathbb{C}}(x, z) + \ell(z, y)d_{\mathbb{C}}(z, y)$.

Then $d_{\mathbb{C}}$ is called,

1. Complex valued dislocated metric on X if $d_{\mathbb{C}}$ satisfies D_1, D_2 and D_3 .
2. Complex valued controlled dislocated metric on X if $d_{\mathbb{C}}$ satisfies D_1, D_2 and D_4 .
3. Complex valued double controlled dislocated metric on X if $d_{\mathbb{C}}$ satisfies D_1, D_2 and D_5 .

The pair $(X, d_{\mathbb{C}})$ is called complex valued dislocated metric space/ complex valued controlled dislocated metric space / complex valued double controlled dislocated metric space respectively. Now throughout this paper $(X, d_{\mathbb{C}})$ stands for complex valued double controlled dislocated metric space.

Definition 3.2 [10] Let $(X, d_{\mathbb{C}})$ be a complex valued double controlled dislocated metric space, $\{x_n\}$ be a sequence in X and $X \in X$.

- (a) The sequence $\{x_n\}$ is said to be complex valued $d_{\mathbb{C}}$ -convergent in $(X, d_{\mathbb{C}})$ and converges to x , if for every $\epsilon > 0$ there exists $n_0 \in \mathbb{N}$ such that $d(x_n, x) < \epsilon$ for all $n > n_0$ and is denoted by $x_n \rightarrow x$ as $n \rightarrow \infty$.
- (b) The sequence $\{x_n\}$ is called complex valued $d_{\mathbb{C}}$ Cauchy sequence in $(X, d_{\mathbb{C}})$ if $\lim_{n \rightarrow \infty} d(x_n, x_{n+p}) = 0$ for all $p > 0$.
- (c) If every complex valued $d_{\mathbb{C}}$ Cauchy sequence in X is converges to some $x \in X$, then $(X, d_{\mathbb{C}})$ is said to be a complete complex valued dislocated metric space.

Lemma 3.1 [10] Let $(X, d_{\mathbb{C}})$ be a complex valued double controlled dislocated metric space and let $\{x_n\}$ be a sequence in X . Then $\{x_n\}$ converges to x if and only if $|d_{\mathbb{C}}(x_n, x)| \rightarrow 0$ as $n \rightarrow \infty$.





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Lemma 3.2 [10] Let (X, d_C) be a complex valued double controlled dislocated metric space and let $\{j_n\}$ be a sequence in X . Then $\{j_n\}$ is a complex valued Cauchy sequence if and only if $|d_C(j_n, j_{n+m})| \rightarrow 0$ as $n \rightarrow \infty$.

Lemma 3.3 [10] Let (X, d_C) be a complex valued double controlled dislocated metric space. Then

- (A) If $d_C(x, y) = 0$ then $d_C(x, x) = d_C(y, y) = 0$;
- (B) If $\{x_n\}$ is a sequence such that $\lim_{n \rightarrow \infty} d_C(x_n, x_{n+1}) = 0$ then we have $\lim_{n \rightarrow \infty} d_C(x_n, x_n) = \lim_{n \rightarrow \infty} d_C(x_{n+1}, x_{n+1}) = 0$;
- (C) If $x \neq y$, then $d_C(x, y) > 0$;
- (D) If $d_C(x, x) \leq \frac{2}{n} \sum_{i=1}^n d_C(x, x_i)$ for all $x, x_i \in X$, where $1 \leq i \leq n$.

Theorem 3.2 [10] Let (X, d_C) be a complete complex valued double controlled dislocated metric space and let $S, T: X \rightarrow X$ satisfy,

$$a^b d_C(Sx, Ty) \lesssim \lambda d_C(x, y) + \mu \frac{d_C(x, Sx)d_C(y, Ty)}{1 + d_C(x, y)} + \eta \frac{d_C(x, Ty)d_C(y, Sx)}{1 + d_C(x, y)}$$

for all $x, y \in X$ whenever $0 < d_C(x, y)$ where $a, b \geq 1$ and λ, μ, η are non-negative real numbers with $\lambda + \mu + \eta < 1$. For $j_0 \in X$, choose $x_n = T^n x_0$. Assume that,

$$\sup_{m \geq 1} \lim_{i \rightarrow \infty} \frac{\wp(x_{i+1}, x_{i+2})}{\wp(x_i, x_{i+1})} \ell(x_{i+1}, x_m) < \frac{1}{A}, \text{ where } A = \frac{\lambda + 2\eta}{a^b - \mu - 2\eta}$$

In addition, for each $x \in X$ suppose that $\lim_{n \rightarrow \infty} \wp(x, x_n)$ and $\lim_{n \rightarrow \infty} \ell(x_n, x)$ exist and are finite. Then S, T have a unique common fixed point.

Theorem 3.3 Let (X, d_C) be a complete complex valued double controlled dislocated metric space and let $S, T: X \rightarrow X$ satisfy,

$$d_C(Sx, Ty) \lesssim (\theta(x) - \theta(Sx))\Psi(x, y) \tag{1}$$

where,

$$\Psi(x, y) = \max \left\{ d_C(x, y), d_C(x, Sx), d_C(y, Ty), \frac{d_C(x, Sx)d_C(y, Ty)}{4d_C(Sx, Ty)}, \frac{d_C(x, Ty)d_C(y, Sx)}{2[d_C(x, Sx) + d_C(y, Ty)]} \right\} \text{ and}$$

$\theta: X \rightarrow \mathbb{R}$ is bounded from below $\{\inf \theta(X)\} < -\infty$. For $x_0 \in X$, choose $x_n = T^n x_0$. Assume that,

$$\sup_{m \geq 1} \lim_{i \rightarrow \infty} \frac{\wp(x_{i+1}, x_{i+2})}{\wp(x_i, x_{i+1})} \ell(x_{i+1}, x_m) < \frac{1}{h}, \text{ where } h \in (0, 1). \text{ In addition, for each } x \in X \text{ suppose that}$$

$\lim_{n \rightarrow \infty} \wp(x, x_n)$ and $\lim_{n \rightarrow \infty} \ell(x_n, x)$ exist and are finite. Then S and T have a unique common fixed point.

Proof. Let x_0 be an arbitrary point in X . Consider the sequence $x_n = T^n x_0$ in X that satisfies the hypothesis of the theorem and define

$$x_{2n+1} = Sx_{2n} \text{ and } x_{2n+2} = Tx_{2n+1}, \quad n = 0, 1, 2, \dots$$

Consider,

$$d_C(x_{2n+1}, x_{2n+2}) = d_C(Sx_{2n}, Tx_{2n+1}) \lesssim (\theta(x_{2n}) - \theta(Sx_{2n}))\Psi(x_{2n}, x_{2n+1}). \tag{2}$$

where, $\Psi(x_{2n}, x_{2n+1})$

$$\begin{aligned} &= \max \left\{ d_C(x_{2n}, x_{2n+1}), d_C(x_{2n}, Sx_{2n}), d_C(x_{2n+1}, Tx_{2n+1}), \frac{d_C(x_{2n}, Sx_{2n})d_C(x_{2n+1}, Tx_{2n+1})}{4d_C(Sx_{2n}, Tx_{2n+1})}, \right. \\ &\quad \left. \frac{d_C(x_{2n}, Tx_{2n+1})d_C(x_{2n+1}, Sx_{2n})}{2[d_C(x_{2n}, Sx_{2n}) + d_C(x_{2n+1}, Tx_{2n+1})]} \right\} \\ &= \max \left\{ d_C(x_{2n}, x_{2n+1}), d_C(x_{2n}, x_{2n+1}), d_C(x_{2n+1}, x_{2n+2}), \frac{d_C(x_{2n}, x_{2n+1})d_C(x_{2n+1}, x_{2n+2})}{4d_C(x_{2n+1}, x_{2n+2})}, \right. \\ &\quad \left. \frac{d_C(x_{2n}, x_{2n+2})d_C(x_{2n+1}, x_{2n+1})}{2[d_C(x_{2n}, x_{2n+1}) + d_C(x_{2n+1}, x_{2n+2})]} \right\} \\ &= \max \left\{ d_C(x_{2n}, x_{2n+1}), d_C(x_{2n}, x_{2n+1}), d_C(x_{2n+1}, x_{2n+2}), \frac{d_C(x_{2n}, x_{2n+1})d_C(x_{2n+1}, x_{2n+2})}{4d_C(x_{2n+1}, x_{2n+2})}, \right. \\ &\quad \left. \frac{2d_C(x_{2n}, x_{2n+2})d_C(x_{2n}, x_{2n+1})}{2[d_C(x_{2n}, x_{2n+2})]} \right\} \\ &= \max\{d_C(x_{2n}, x_{2n+1}), d_C(x_{2n+1}, x_{2n+2})\} \end{aligned}$$

If $\Psi(x_{2n}, x_{2n+1}) = d_C(x_{2n+1}, x_{2n+2})$, from (3.2)





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$d_{\mathbb{C}}(x_{2n+1}, x_{2n+2}) \lesssim (\theta(x_{2n}) - \theta(Sx_{2n}))d_{\mathbb{C}}(x_{2n+1}, x_{2n+2})$, a contradiction

Hence, $\Psi(x_{2n}, x_{2n+1}) = d_{\mathbb{C}}(x_{2n}, x_{2n+1})$, from (3.2)

$$d_{\mathbb{C}}(x_{2n+1}, x_{2n+2}) \lesssim (\theta(x_{2n}) - \theta(Sx_{2n}))d_{\mathbb{C}}(x_{2n}, x_{2n+1})$$

$$d_{\mathbb{C}}(x_{2n+1}, x_{2n+2}) \lesssim (\theta(x_{2n}) - \theta(x_{2n+1}))d_{\mathbb{C}}(x_{2n}, x_{2n+1}).$$

Similarly,

$$d_{\mathbb{C}}(x_{2n+2}, x_{2n+3}) = d_{\mathbb{C}}(Sx_{2n+1}, Tx_{2n+2}) \lesssim (\theta(x_{2n+1}) - \theta(Sx_{2n+1}))\Psi(x_{2n+1}, x_{2n+2}) \quad (3)$$

where,

$$\Psi(x_{2n+1}, x_{2n+2}) = \max \left\{ d_{\mathbb{C}}(x_{2n+1}, x_{2n+2}), d_{\mathbb{C}}(x_{2n+1}, Sx_{2n+1}), d_{\mathbb{C}}(x_{2n+2}, Tx_{2n+2}), \frac{d_{\mathbb{C}}(x_{2n+1}, Sx_{2n+1})d_{\mathbb{C}}(x_{2n+2}, Tx_{2n+2})}{4d_{\mathbb{C}}(Sx_{2n+1}, Tx_{2n+2})}, \frac{d_{\mathbb{C}}(x_{2n+1}, Tx_{2n+2})d_{\mathbb{C}}(x_{2n+2}, Sx_{2n+1})}{2[d_{\mathbb{C}}(x_{2n+1}, Sx_{2n+1}) + d_{\mathbb{C}}(x_{2n+2}, Tx_{2n+2})]} \right\}$$

$$\max \left\{ d_{\mathbb{C}}(x_{2n+1}, x_{2n+2}), d_{\mathbb{C}}(x_{2n+1}, x_{2n+2}), d_{\mathbb{C}}(x_{2n+2}, x_{2n+3}), \frac{d_{\mathbb{C}}(x_{2n+1}, x_{2n+2})d_{\mathbb{C}}(x_{2n+2}, x_{2n+3})}{4d_{\mathbb{C}}(x_{2n+2}, x_{2n+3})}, \frac{d_{\mathbb{C}}(x_{2n+1}, x_{2n+3})d_{\mathbb{C}}(x_{2n+2}, x_{2n+2})}{2[d_{\mathbb{C}}(x_{2n+1}, x_{2n+2}) + d_{\mathbb{C}}(x_{2n+2}, Tx_{2n+3})]} \right\}$$

$$= \max \left\{ d_{\mathbb{C}}(x_{2n+1}, x_{2n+2}), d_{\mathbb{C}}(x_{2n+1}, x_{2n+2}), d_{\mathbb{C}}(x_{2n+2}, x_{2n+3}), \frac{d_{\mathbb{C}}(x_{2n+1}, x_{2n+2})d_{\mathbb{C}}(x_{2n+2}, x_{2n+3})}{4d_{\mathbb{C}}(x_{2n+2}, x_{2n+3})}, \frac{2d_{\mathbb{C}}(x_{2n+1}, x_{2n+3})d_{\mathbb{C}}(x_{2n+1}, x_{2n+2})}{2[d_{\mathbb{C}}(x_{2n+1}, x_{2n+3})]} \right\}$$

$$= \max\{d_{\mathbb{C}}(x_{2n+1}, x_{2n+2}), d_{\mathbb{C}}(x_{2n+2}, x_{2n+3})\}$$

If $\Psi(x_{2n+1}, x_{2n+2}) = d_{\mathbb{C}}(x_{2n+2}, x_{2n+3})$, from (3.3)

$d_{\mathbb{C}}(x_{2n+2}, x_{2n+3}) \lesssim (\theta(x_{2n+1}) - \theta(Sx_{2n+1}))d_{\mathbb{C}}(x_{2n+2}, x_{2n+3})$, a contradiction

Hence, $\Psi(x_{2n+1}, x_{2n+2}) = d_{\mathbb{C}}(x_{2n+1}, x_{2n+2})$, from (3.3)

$$d_{\mathbb{C}}(x_{2n+2}, x_{2n+3}) \lesssim (\theta(x_{2n+1}) - \theta(Sx_{2n+1}))d_{\mathbb{C}}(x_{2n+1}, x_{2n+2}).$$

$$\lesssim (\theta(x_{2n+1}) - \theta(x_{2n+2}))d_{\mathbb{C}}(x_{2n+1}, x_{2n+2}).$$

Hence we conclude that

$$d_{\mathbb{C}}(x_n, x_{n+1}) \lesssim (\theta(x_{n-1}) - \theta(x_n))d_{\mathbb{C}}(x_{n-1}, x_n); \text{ for each } n \in \mathbb{N}.$$

So we have,

$$\frac{d_{\mathbb{C}}(x_n, x_{n+1})}{d_{\mathbb{C}}(x_{n-1}, x_n)} \lesssim (\theta(x_{n-1}) - \theta(x_n)),$$

$$\Rightarrow \frac{|d_{\mathbb{C}}(x_n, x_{n+1})|}{|d_{\mathbb{C}}(x_{n-1}, x_n)|} \leq (\theta(x_{n-1}) - \theta(x_n)), \text{ for each } n \in \mathbb{N}.$$

Thus the sequence $\{\theta(x_n)\}$ is necessarily positive and non-increasing. Hence it converges to some $g \geq 0$. On other hand for each $n \in \mathbb{N}$, we have,

$$\sum_{m=1}^n \frac{|d_{\mathbb{C}}(x_m, x_{m+1})|}{|d_{\mathbb{C}}(x_{m-1}, x_m)|} \leq \sum_{m=1}^n (\theta(x_{m-1}) - \theta(x_m))$$

$$= (\theta(x_0) - \theta(x_1)) + (\theta(x_1) - \theta(x_2)) + \dots + (\theta(x_{n-1}) - \theta(x_n))$$

$$= (\theta(x_0) - \theta(x_n))$$

$$\rightarrow \theta(x_0) - g < \infty \text{ as } n \rightarrow \infty.$$





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which yields, $\sum_{m=1}^n \frac{|d_C(x_m, x_{m+1})|}{|d_C(x_{m-1}, x_m)|} < \infty$.

Accordingly we have, $\lim_{m \rightarrow \infty} \frac{|d_C(x_m, x_{m+1})|}{|d_C(x_{m-1}, x_m)|} = 0$. (4)

from (3.3) there exist $\rho \in (0, 1)$ such that $\frac{|d_C(x_m, x_{m+1})|}{|d_C(x_{m-1}, x_m)|} \leq \rho$ for all $m \geq m_0$. which yields that,

$$|d_C(x_m, x_{m+1})| \leq \rho |d_C(x_{m-1}, x_m)| \text{ for all } m \geq m_0.$$

By following the same pattern as followed in theorem (3.1), we obtain that the sequence $\{x_n\}$ converges to some $a \in X$. i.e. $\lim_{n \rightarrow \infty} |d_C(x_n, a)| = 0$. (5)

Consider,

$$|d_C(x_{2n+1}, x_{2n+2})| \leq \wp(x_{2n+1}, a) |d_C(x_{2n+1}, a)| + \ell(a, x_{2n+2}) |d_C(a, x_{2n+2})|.$$

Letting $n \rightarrow \infty$, we get $|d_C(x_{2n+1}, x_{2n+2})| \rightarrow 0$. (6)

We claim that $a = Sa$. Suppose $a \neq Sa$. i.e. $0 < d_C(a, Sa)$.

Consider,

$$\begin{aligned} |d_C(a, Sa)| &\leq \wp(a, x_{2n+2}) |d_C(a, x_{2n+2})| + \ell(x_{2n+2}, Sa) |d_C(x_{2n+2}, Sa)| \\ &\leq \wp(a, x_{2n+2}) |d_C(a, x_{2n+2})| + \ell(x_{2n+2}, Sa) |d_C(Sa, Tx_{2n+1})| \\ &\leq \wp(a, x_{2n+2}) |d_C(a, x_{2n+2})| + \ell(x_{2n+2}, Sa) (\Theta(a) - \Theta(Sa)) \Psi(a, x_{2n+1}). \end{aligned} \quad (7)$$

where,

$$\begin{aligned} \Psi(a, x_{2n+1}) &= \max \left\{ \begin{aligned} &d_C(a, x_{2n+1}), d_C(a, Sa), d_C(x_{2n+1}, Tx_{2n+1}), \frac{d_C(a, Sa) d_C(x_{2n+1}, Tx_{2n+1})}{4d_C(Sa, Tx_{2n+1})} \\ &\frac{d_C(a, Tx_{2n+1}) d_C(x_{2n+1}, Sx_{2n+1})}{2[d_C(a, Sa) + d_C(x_{2n+1}, Tx_{2n+1})]} \end{aligned} \right\} \\ \Psi(a, x_{2n+1}) &= \max \left\{ \begin{aligned} &d_C(a, x_{2n+1}), d_C(a, Sa), d_C(x_{2n+1}, x_{2n+2}), \frac{d_C(a, Sa) d_C(x_{2n+1}, x_{2n+2})}{4d_C(Sa, x_{2n+2})} \\ &\frac{d_C(a, x_{2n+2}) d_C(x_{2n+1}, x_{2n+2})}{2[d_C(a, Sa) + d_C(x_{2n+1}, x_{2n+2})]} \end{aligned} \right\} \end{aligned}$$

If $\Psi(a, x_{2n+1}) = d_C(a, x_{2n+1})$, from (7) we have

$$|d_C(a, Sa)| \leq \wp(a, x_{2n+2}) |d_C(a, x_{2n+2})| + \ell(x_{2n+2}, Sa) (\Theta(a) - \Theta(Sa)) |d_C(a, x_{2n+1})|.$$

Taking limit $n \rightarrow \infty$, we get $|d_C(a, Sa)| = 0$. a contradiction and hence $a = Sa$.

If $\Psi(a, x_{2n+1}) = d_C(a, Sa)$, from (7) we have

$$|d_C(a, Sa)| \leq \wp(a, x_{2n+2}) |d_C(a, x_{2n+2})| + \ell(x_{2n+2}, Sa) (\Theta(a) - \Theta(Sa)) |d_C(a, Sa)|.$$

Taking limit $n \rightarrow \infty$, and using (5) and (6) we get $|d_C(a, Sa)| = 0$, a contradiction.

Hence $a = Sa$.

If $\Psi(a, x_{2n+1}) = d_C(x_{2n+1}, x_{2n+2})$, from (7) we have

$$|d_C(a, Sa)| \leq \wp(a, x_{2n+2}) |d_C(a, x_{2n+2})| + \ell(x_{2n+2}, Sa) (\Theta(a) - \Theta(Sa)) |d_C(x_{2n+1}, x_{2n+2})|.$$

Letting $n \rightarrow \infty$, and using (5) and (6) we get $|d_C(a, Sa)| = 0$, a contradiction.

Hence $a = Sa$.

If $\Psi(a, x_{2n+1}) = \frac{d_C(a, Sa) d_C(x_{2n+1}, x_{2n+2})}{4d_C(Sa, Tx_{2n+2})}$, from (7) we have

$$\begin{aligned} |d_C(a, Sa)| &\leq \wp(a, x_{2n+2}) |d_C(a, x_{2n+2})| + \ell(x_{2n+2}, Sa) \\ &\quad (\Theta(a) - \Theta(Sa)) \left| \frac{d_C(a, Sa) d_C(x_{2n+1}, x_{2n+2})}{4d_C(Sa, Tx_{2n+2})} \right| \end{aligned}$$

Letting $n \rightarrow \infty$, and using (5) and (6) we get $|d_C(a, Sa)| = 0$, a contradiction.

Hence $a = Sa$.

If $\Psi(a, x_{2n+1}) = \frac{d_C(a, x_{2n+2}) d_C(x_{2n+1}, x_{2n+2})}{2[d_C(a, Sa) + d_C(x_{2n+1}, x_{2n+2})]}$, from (7) we have

$$\begin{aligned} |d_C(a, Sa)| &\leq \wp(a, x_{2n+2}) |d_C(a, x_{2n+2})| + \\ &\quad \ell(x_{2n+2}, Sa) (\Theta(a) - \Theta(Sa)) \left| \frac{d_C(a, x_{2n+2}) d_C(x_{2n+1}, x_{2n+2})}{2[d_C(a, Sa) + d_C(x_{2n+1}, x_{2n+2})]} \right| \end{aligned}$$

Letting $n \rightarrow \infty$, and using (5) and (6) we get $|d_C(a, Sa)| = 0$, a contradiction.

Hence $a = Sa$.

Similarly, we can prove $a = Ta$. Now we will prove that S and T have a unique common fixed point.

Let a and a^* be two common fixed point of S and T . So that $a \neq a^*$, i.e. $0 < d_C(a, a^*)$.

Consider,

$$d_C(a, a^*) = d_C(Sa, Ta^*) \leq (\Theta(a) - \Theta(Sa)) \Psi(a, a^*). \quad (8)$$





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where,

$$\Psi(a, a^*) = \max \left\{ d_C(a, a^*), d_C(a, Sa), d_C(a^*, Ta^*), \frac{d_C(a, Sa)d_C(a^*, Ta^*)}{4d_C(Sa, Ta^*)}, \frac{d_C(a, Ta^*)d_C(a^*, Sa)}{2[d_C(a, Sa) + d_C(a^*, Ta^*)]} \right\}$$

$$\Psi(a, a^*) = \max \left\{ d_C(a, a^*), d_C(a, a), d_C(a^*, a^*), \frac{d_C(a, a)d_C(a^*, a^*)}{4d_C(a, a^*)}, \frac{d_C(a, a^*)d_C(a^*, a)}{2[d_C(a, a) + d_C(a^*, a^*)]} \right\}$$

$\Psi(a, a^*) = d_C(a, a^*)$. Now from (8)

$d_C(a, a^*) \lesssim (\theta(a) - \theta(Sa))d_C(a, a^*)$. a contradiction.

Hence, $|d_C(a, a^*)| = 0$. i.e. $a = a^*$.

Thus S and T have a unique common fixed point.

Example 3.2 Let $X = \{1,2,3\}$ and $d_C: X \times X \rightarrow \mathbb{C}$ by

$$d_C(1,2) = d_C(2,1) = i; d_C(3,2) = d_C(2,3) = 1 + i; d_C(1,3) = d_C(3,1) = \frac{1+i}{2}$$

$d_C(1,1) = d_C(2,2) = d_C(3,3) = i$. Define $\wp, \ell: X \times X \rightarrow [1, \infty)$ by

$$\wp(0,1) = \wp(1,0) = \frac{11}{10}; \wp(1,2) = \wp(2,1) = \frac{5}{8}; \wp(0,2) = \wp(2,0) = 1; \wp(0,0) = 1.$$

$$z(0,1) = z(1,0) = \frac{11}{10}; z(1,2) = z(2,1) = \frac{5}{4}; z(0,2) = z(2,0) = \frac{5}{2}; z(0,0) = 1.$$

Then (X, d_C) is a complete complex valued double controlled dislocated metric space.

Define the mappings $S, T: X \rightarrow X$ by $S(1) = S(3) = 1, S(2) = 3; T(1) = 1, T(2) = T(3) = 2$.

$\theta: S \rightarrow [0, \infty)$ as $\theta(1) = 2, \theta(2) = 4, \theta(3) = 3$. Thus we have,

Case 1: If $x = 2, y = 3$.

$$d_C(S(2), T(3)) = d_C(3,2) = 1 + i$$

Now consider,

$$\begin{aligned} & (\theta(2) - \theta(S(2)))\Psi(2,3) \\ &= (4 - 3) \max \left\{ d_C(2,3), d_C(2, S(2)), d_C(3, T(3)), \frac{d_C(2, S(2))d_C(3, T(3))}{4d_C(S(2), T(3))}, \right. \\ & \quad \left. \frac{d_C(2, T(3))d_C(3, S(2))}{2[d_C(2, S(2)) + d_C(3, T(3))]} \right\} \\ &= \max \left\{ d_C(2,1), d_C(2, 3), d_C(3, 2), \frac{d_C(2,3)d_C(3,2)}{4d_C(3,2)} \right\} \\ & \quad \left. \frac{d_C(2,2)d_C(3,3)}{2[d_C(2,3) + d_C(3,2)]} \right\} \\ &= \max \left\{ 1 + i, 1 + i, 1 + i, \frac{1+i}{4}, \frac{-1}{4i+4} \right\}. \\ & \quad = 1 + i \end{aligned}$$

Case 2: If $j = 2, k = 1$.

$$d_C(S(2), T(1)) = d_C(3,1) = \frac{1+i}{2}$$

Now consider,

$$\begin{aligned} & (\theta(2) - \theta(S(2)))\Psi(2,1) \\ &= (4 - 3) \max \left\{ d_C(2,1), d_C(2, S(2)), d_C(1, T(1)), \frac{d_C(2, S(2))d_C(1, T(1))}{4d_C(S(2), T(1))}, \right. \\ & \quad \left. \frac{d_C(2, T(1))d_C(1, S(2))}{2[d_C(2, S(2)) + d_C(1, T(1))]} \right\} \\ &= \max \left\{ d_C(2,1), d_C(2, 3), d_C(1, 1), \frac{d_C(2,3)d_C(1, 1)}{4d_C(3,1)} \right\} \\ & \quad \left. \frac{d_C(2,1)d_C(1,2)}{2[d_C(2,3) + d_C(1,1)]} \right\} \\ &= \max \left\{ i, 1 + i, i, \frac{i}{2}, \frac{-1}{2+4i} \right\} \\ &= 1 + i. \end{aligned}$$





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Case 3: If $x = 3, y = 2$.

$$d_c(S(3), T(2)) = d_c(1, 2) = i$$

Now consider,

$$\begin{aligned} & (\theta(3) - \theta(S(3)))\Psi(3, 2) \\ &= (3 - 2) \max \left\{ d_c(3, 2), d_c(3, S(3)), d_c(2, T(2)), \frac{d_c(3, S(3))d_c(2, T(2))}{4d_c(S(3), T(2))}, \right. \\ & \quad \left. \frac{d_c(3, T(2))d_c(2, S(3))}{2[d_c(3, S(3)) + d_c(2, T(2))]} \right\} \\ &= \max \left\{ d_c(3, 2), d_c(3, 1), d_c(2, 2), \frac{d_c(3, 1)d_c(2, 2)}{4d_c(1, 2)}, \right. \\ & \quad \left. \frac{d_c(3, 2)d_c(2, 1)}{2[d_c(3, 1) + d_c(2, 2)]} \right\} \\ &= \max \left\{ 1 + i, \frac{1 + i}{2}, i, \frac{1 + i}{8}, \frac{-1 + i}{1 + 3i} \right\} \\ &= 1 + i. \end{aligned}$$

Hence all conditions of theorem (3.4) managed in the above example, thereby we can conclude that 1 is the common fixed point of S and T .

DISCUSSIONS

In this article, we extended the study of fixed-point theory by using the notions of weak compatibility in context of complex valued metric spaces with the concept of dislocated metric spaces. We constructed some theorems which are more general than earlier results. Some examples are also furnished by us to show the applicability of our new results. Our results may be helpful for investigation of Kannan contraction, Chatterjee contraction in controlled and double controlled type metric spaces.

REFERENCES

1. P. Hitzler, A.K. Seda, Dislocated Topologies, Proceeding of Slovakian conference in Applied Mathematics. Bratislava April 2000
2. F.M. Zeyada, G.H.Hassan, M.A.Ahmed, A generalization of a fixed point theorem due to Hitzler and Seda in dislocated Quasi-metric spaces, The Arabian journal of science and engineering. 31 (2006) 111-114.
3. C.T. Aage, J.N. Salunke, The Results on fixed point in Dislocated and dislocated Quasi-metric spaces, Applied Mathematical Sciences. 2 (2008) 2941-2948.
4. K. Jha, D. Panthi, A common fixed point theorem in dislocated metric space, Applied Mathematical Sciences. 6 (2012) 4497-4503
5. K. Prudhvi, Common fixed point for four self mapping in dislocated metric space, American journal of applied mathematics and statistics. 6 (2018) 6-8.
6. A. Azam, B. Fisher, M. Khan, Common fixed point theorems in complex valued metric spaces, Numerical Functional Analysis and Optimization. 32(3) (2011) 243-253. <https://doi.org/10.1080/01630563.2011.533046>
7. W. Sintunavarat, P. Kumam, Generalized common fixed point theorems in complex valued metric spaces and applications, J. Inequal. Appl. (2012) 84.
8. O. Ege, I Karaca, Complex valued dislocated metric spaces. Korean J.Math.26 (2018) No.4 809-822.DOI:10.11568/kjm.2018.26.4.809
9. D. Lateef, Fisher type fixed point results in controlled metric spaces, J. Math. Comput. Sci. 20, 234-240, (2020).DOI:10.22436/jmcs.020.03.06
10. G.Yadav, R.K. Sharma, G.L. Prajapati, Solition of k- fractional integral via fixed point using complex valued double controlled dislocated metric spaces, IEEE Explore. (2021).DOI: 10.1109/TRIBES52498.2021.9751627
11. N. Mlaiki, H. Hyadi, N. Souayah, T. Abdeljawad, controlled metric type spaces and the related contraction principle, Mathematics6,(2018) 194. <https://doi.org/10.3390/math6100194>





Rinku Jain et al.,

12. Z. Ma, J. Ahmad, A.E. Al mazrooei, Fixed point results for generalized contractions in controlled metric spaces with applications, AIMS MATH. 8, 529-549 (2023).





Future Prospects of Indian Traditional Medicine for Snake Bite Treatment: A Comprehensive Review

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ABSTRACT

In India, snake bites have been a community hazard for ages. South Asia has the most reported snake bites in the world. In the rural areas of the country, modern treatments for snake bites, such as antivenom therapy and serological therapy, are logistically a huge task due to the unavailability of proper storage, handling, and educated medical personnel. Throughout the country, various communities have identified and developed their own treatment principles to treat envenoming. Thus, pragmatically, the use of local herbal therapy seems to be the alternative option. But there is only limited verified evidence on the effectiveness of the ethnic medical remedies. Thus, identifying and standardizing the communal medical treatments is necessary for the rational treatment of snake bite envenomation. This review emphasizes the importance of identifying effective ethnobotanicals against snake bites and discusses the future of Indian traditional medicines and the need for evaluation of the proposed effectiveness against snake bites. Promoting the role of Ayurvedic, Siddha, and folk medical practices as complementary treatments along with modern pharmacological treatments to promote rational therapy against snake bites.

Keywords: Indian Traditional Medicine, Snakebites, Ethnobotanicals, Antivenom.





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INTRODUCTION

Snake bites have been a life-threatening medical emergency throughout human history. Snake bites have often been concentrated in tropical and sub-tropical climates such as the Indian Subcontinent, Sub-Saharan Africa, Latin America, and Southeast Asia[1]. Snake bites are primarily reported in the rural and suburban areas of tropical climates [2]. About a third of reported snake bites are venomous. The non-venomous bites must also be treated using appropriate medical treatments, as they might pose a viable area for other infections, thus increasing the risk of morbidity[1],[2]. Epidemiological studies suggest that globally, an estimate of 5.4 million people are bitten by snakes each year, with 1.8 to 2.7 million cases of envenoming officially. The snake bites have mortality numbers ranging from 81,400 to 1,37,880. The morbidity caused by the same, such as amputations and other disabilities, may be estimated to be three times the mortality rate. Followed by Asia, Africa reports the most snake bite cases, numbering up to 580,000 officially. Envenomation affects people in rural, nations with poor and moderate incomes. The proportion of bites to deaths rises significantly in nations with underdeveloped health systems and limited access to medications[3]. As the country with the largest population, India may have non-fatal snake bites numbering up to 1.2 million per year[4],[5]. There are roughly 2000 distinct species of snakes in the globe; 300 of which are found in India, and 52 of them have been identified as venomous. Three main families comprise the venomous snakes found in India: Elapidae, Viperidae, and Hydrophidae. The WHO listed snake bites as a neglected tropical illness in 2009; the bites are especially prevalent during the monsoon season.

Snake bites are a long-standing, potentially fatal condition[6],[7]. It has also been found that there is a huge discrepancy between the reported snake bites and the actual incidences. Through the surveys of Majumder et al. (2014) and Mohapatra et al. (2011), it's estimated that only a proportion of 7.23 percent of snake bite deaths are officially reported. The bites were more commonly seen on males than females, peaking at the ages of 17–29. Out of all snake bite victims, just 22.19 percent attended the hospital[4],[5]. In India, Common Krait is found to be the species that causes the highest proportion of snake bite-related deaths, numbering at 65.7 percent. This might be due to the unavailability of anti-snake venom for Krait. Other factors might be attributed, such as the unavailability of resources, a proper systematic treatment procedure, a lack of practical experience, and a time delay due to the patient considering ineffective home remedies or ignorance[6],[7]. Envenomation by snakes and other animals has often had a negative impact on rural communities. Thus, various communities have identified and developed primary treatments for snake envenomation using various plant- and animal-based compounds[1],[2]. These indigenous plant species used by a community or a culture are called ethnobotanicals. Many ethnobotanicals used in the treatment of snake bites possess adjuvant therapeutic effects such as good antimicrobial activity, antipyretics, and wound healing factors, thus improving the condition of the patient. Analytical tests conducted both in vivo and in vitro have revealed that some ethnobotanicals are effective against snake bites, and some are capable of neutralizing the venom[1],[2],[7]. This review aims to enlighten a better understanding of the use of ethnobotanicals in the form of traditional Indian medical disciplines such as Ayurveda, Siddha, and Naattu vaithiyam in the treatment of snake bites. Thus, by promoting awareness of traditional medicines and verifying their effectiveness.

Common Venomous Snakes in India

Snakes are limbless carnivorous reptiles that belong to the Serpentes suborder within the Reptilia class[8]. Venomous snakes are a part of India's diverse biodiversity. Four venomous snakes are common throughout the country. Since known as "THE BIG FOUR." [9] They are: the 'Indian cobra (*Naja naja*), the Common' krait (*Bungarus caeruleus*), the Russell's viper (*Daboia russelii*), and 'the Saw scaled viper' (*Echis carinatus*) These four snakes cause the majority of deaths due to envenomation[10]. Venomous snakes release venom through their fangs, which are linked to venom and glands through canals. The venom glands are altered parotid salivary glands situated behind the eye [11]. Venomous snakes other than "THE BIG FOUR" are *Craspedocephalus malabaricus* (the Malabar pit viper), *Bungarus fasciatus* (the banded krait), *Craspedocephalus gramineus* (the bamboo pit viper), *Hypnale hypnale* (the hollow-nosed pit





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viper), and *Trimeresurus andersonii* (the Andaman pit viper) [12]. The habitat, description, and type of venom of “The Big Four” snakes are given below.

Indian cobra (*Naja naja*)

- **Description:** It consists of a mark on the back of its hood; it has a slender body and hood and can reach lengths of up to 6 feet [13].
- **Habitat:** Found in grasslands, forests, and agricultural areas [13].
- **Venom:** The venom is primarily neurotoxic [14].

Common krait (*Bungarus caeruleus*)

- **Description:** It is a nocturnal snake with a glossy black or bluish-black color and thin white bands across its body. It has a relatively small head compared to its body [15].
- **Habitat:** Found in rural areas, agricultural fields, and human settlements [15].
- **Venom:** The venom is neurotoxic [15].

Russel’s viper (*Daboia russelii*)

- **Description:** It is a snake with a triangular-shaped head and a distinctive pattern on its back, consisting of dark brown or black spots bordered by white or yellow [16].
- **Habitat:** found in a variety of conditions, including woodlands, grasslands, and agricultural fields [16].
- **Venom:** The venom is both neurotoxic and vasculotoxic [17].

Saw scaled viper (*Echis carinatus*)

- **Description:** It is a small to medium-sized snake with a characteristic saw-like pattern on its scales [18].
- **Habitat:** Found in arid regions, rocky terrain, and scrublands [18].
- **Venom:** The venom is hemotoxic [19].

Clinical Features of Snake bite

The clinical features of envenomation vary based on the species of snake, nature, concentration, and reaction of the victim to the venom²⁰. Some common clinical features of envenomation are given below.

Role of Indian Traditional Medicine in Snake Bite Envenomation

Ayurveda is a branch of Indian medicine that has a history of utilizing herbs as treatments for various health issues. Many pieces of evidence prove the use of Ayurveda for the cure of snakebites [21]. Although these traditional remedies hold cultural and historical value, their effectiveness in treating snakebites lacks scientific evidence [22]. However, certain herbs do possess antivenom properties that can neutralize the venom's effects. Here are some details about how traditional Indian medicine treats snakebite victims. Ayurveda utilizes different medicinal plants known to have antibacterial, detoxifying, and anti-inflammatory properties [22]. Some herbs in Ayurveda are believed to have detoxification and immune-boosting properties, such as Amla, Ashwagandha, Tulsi, etc [22]. Herbs such as Triphala, Ginger, and Punarnava contain anti-inflammatory qualities that make them useful for treating pain and swelling [22],[23]. Tribal people believe pastes made from multiple herbs can heal snakebite envenomation[22].

The Future of Snakebite Management: Insights from Indian Herbal Remedies

Traditional medicine could have been taken into consideration decades ago, but combining it with contemporary medicine to treat snakebite could offer a fresh take on envenomation therapy. Traditional medicine in India, including Ayurveda, has many herbal remedies to offer and ways in which it can be integrated and complement modern snake bite management approaches [24]. The Prayoga Samuccayam contains details on snakebite management. There are a lot of master recipes and their simple and affordable formulations that can be used for the treatment of poisonous situations [25]. *Indian Bdellium*, Neem (*Azadirachta indica*), Turmeric (*Curcuma longa*), Tulsi, and Amla (Indian Gooseberry) are herbs and trees that are grown in most of the houses in the southern part of India. These plants are known to have antivenom properties [26].(Table:1 shows list of medicinal herbs used for snake bite envenomation).





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Challenges

Indian medicine is not free from difficulties and can be used to treat snakebites. It is challenging to develop quality control since there is no standardization [56]. Although it is also drafted in modern medicine-related laws, it is difficult to integrate indigenous knowledge into modern medicine [56]. Therefore, while utilizing traditional Indian medicine and incorporating it into modern approaches, it is necessary to confirm the scientific validity, preserve the cultural heritage, and promote cooperation between traditional healers, researchers, and healthcare workers. Thus, traditional Indian medicine may allow for getting benefits from key stakeholders in the field and making a considerable contribution to global health.

Integrating traditional Indian medicines into modern snakebite protocols

The major problems faced in using antivenom are its high price and availability. The future of treating snakebites will involve a combination of traditional knowledge and modern medicine practices [56]. Research initiatives on ethnobotany will help to find the active pharmaceutical ingredient responsible for neutralizing envenomation and can help in the development of standardization and evidence-based medicine [56]. This integration may result in finding new antivenom substances or alternative treatments that improve the overall effectiveness of snakebite therapy. It is essential to have standardization and quality control measures in place. Creating uniform guidelines for preparing, dosing, and giving herbal formulas will improve reliability and replicability. This includes recognizing and measuring active substances, confirming their effectiveness, and keeping an eye on possible adverse reactions [56]. It is crucial for advancement in snakebite management that collaborative work that includes traditional healers, herbalists, researchers, and healthcare professionals is necessary. Creating spaces for discussion and sharing information can promote mutual understanding and respect among various healthcare approaches. Even though traditional Indian medicine has been used for thousands of years, incorporating it into modern healthcare systems necessitates scientific backing and adherence to evidence-based methods. Recently, researchers and healthcare professionals have shown an increasing curiosity about investigating the possible therapeutic advantages of traditional Indian medicine in treating snakebites [56].

Indian Traditional Medicine: Unravelling its Antivenom Potential

While traditional Indian medicine usually relies on different types of herbs and cures for different diseases, it is crucial to state that the word “antivenom” specifically refers to a cure that is used in relatively modern medicine to ensure that the poison of snakes cannot have any adverse impact on a snakebite victim. According to the text, the specific medicine is made when small amounts of “venom in sub-toxic doses” are injected into such animals as horses or sheep. After the venom is injected, the animals in question start producing antibodies that are chosen to be harvested and then purified to be used for a treatment [57]. According to Ayurveda, certain herbs are useful for snakebite victims. It should be noted that such practice cannot be a substitute for the antivenom treatment used today. Moreover, many of the natural remedies do not have any scientifically proven effect, and in the case of snakebites, it can become unsafe if the patient relies exclusively on them [56]. Nonetheless, some plants, including *Azadirachta indica*, *Butea monosperma*, *Citrus limon*, *Clerodendrum serratum*, and *Areca catechu*, were proven to possess antivenom properties against the majority of venomous snakes in labs and live animals [26]. Some other plants, like *Rauwolfia serpentina*, *Hemidesmus indicus*, and *Alstonia venenata*, could be efficient as well. There are significantly related studies have been shown in (Table:2) as supporting evidences of the review.

CONCLUSIONS

Clinical trials that are well-construct are necessary in order to assess the effectiveness of medicinal herbs as additional treatments for snakebite envenomation! Randomized controlled trials that compare herbal treatments to either placebo or standard care can offer important evidence on how effective they are at enhancing outcomes, such as decreasing morbidity, mortality, and long-term consequences linked to snakebites.





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Conflict of interest

The Authors declare no conflict of interest.

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Nil

REFERENCES

1. Gomes A, Saha A, Chatterjee I, Chakravarty AK. Viper and cobra venom neutralization by beta-sitosterol and stigmaterol isolated from the root extract of *Pluchea indica* Less. (Asteraceae). *Phytomedicine*. 2007 Sep;14(9):637-43. doi: 10.1016/j.phymed.2006.12.020. Epub 2007 Feb 12. PMID: 17293096.
2. Nirmal N, Praba GO, Velmurugan D. Modeling studies on phospholipase A2-inhibitor complexes. *Indian J Biochem Biophys*. 2008 Aug;45(4):256-62. PMID: 18788476.
3. Sánchez EE, Rodríguez-Acosta A. Inhibitors of snake venoms and development of new therapeutics. *Immunopharmacol Immunotoxicol*. 2008;30(4):647-78. doi: 10.1080/08923970802279019. PMID: 18686104.
4. Mohapatra B, Warrell DA, Suraweera W, Bhatia P, Dhingra N, Jotkar RM, Rodriguez PS, Mishra K, Whitaker R, Jha P; Million Death Study Collaborators. Snakebite mortality in India: a nationally representative mortality survey. *PLoS Negl Trop Dis*. 2011 Apr 12;5(4): e1018. doi: 10.1371/journal.pntd.0001018. PMID: 21532748; PMCID: PMC3075236.
5. Majumder, Dayalbandhu1; Sinha, Abhik2; Bhattacharya, Salil Kumar3; Ram, Rama4; Dasgupta, Urmila5; Ram, A.6. Epidemiological Profile of Snake Bite in South 24 Parganas District of West Bengal with Focus on Underreporting of Snake Bite Deaths. *Indian Journal of Public Health* 58(1): p 17-21, Jan–Mar 2014. | DOI: 10.4103/0019-557X.128158
6. Bawaskar HS. Snake bite poisoning: A neglected life-threatening occupational hazard. *Indian J Crit Care* 2014;18: 123-4
7. Snakebite envenoming [Internet]. www.who.int. Available from: <https://www.who.int/news-room/fact-sheets/detail/snakebite-envenoming#:~:text=Key%20facts>
8. Snakes Facts and Information | SeaWorld Parks & Entertainment [Internet]. Seaworld.org. 2019. Available from: <https://seaworld.org/animals/facts/reptiles/snakes/>
9. Joseph, N., Durairaj, S., Gowthaman, O., and Ganesan, V. K. (2022). Updated review on venomous snakebites, therapeutic uses and future prospects of Indian traditional medicine. *Natural Resources for Human Health*, 2(3), pp.293-299. <https://doi.org/10.53365/nrfhh/145144>
10. Simpson ID, Norris RL. Snakes of Medical Importance in India: Is the Concept of the “Big 4” Still Relevant and Useful? *Wilderness & Environmental Medicine*. 2007;18(1):2-9. doi:10.1580/06-WEME-CO-023R1.1
11. Palci A, LeBlanc ARH, Panagiotopoulou O, Cleuren SGC, Mehari Abraha H, Hutchinson MN, Evans AR, Caldwell MW, Lee MSY. Plicidentine and the repeated origins of snake venom fangs. *Proc Biol Sci*. 2021 Aug 11;288(1956):20211391. doi: 10.1098/rspb.2021.1391. Epub 2021 Aug 11. PMID: 34375553; PMCID: PMC8354744.
12. Chakma JK, Menon JC, Dhaliwal RS; Indian Council of Medical Research#. White paper on venomous snakebite in India. *Indian J Med Res*. 2020 Dec;152(6):568-574. doi: 10.4103/ijmr.IJMR_3377_20. PMID: 34145096; PMCID: PMC8224165.
13. Indian cobra | snake [Internet]. Encyclopaedia Britannica. Available from: <https://www.britannica.com/animal/Indian-spectacled-cobra>





Dhivya et al.,

14. WCH Clinical Toxicology Resources [Internet]. web.archive.org. 2014 [cited 2024 Mar 13]. Available from: <https://web.archive.org/web/20141208220244/http://toxinology.com/fusebox.cfm?fuseaction=main.snakes.display&id=SN0041>
15. krait [Internet]. Britannica. [cited 2024 Mar 13]. Available from: <https://kids.britannica.com/students/article/krait/312034#:~:text=The%20largest%20of%20the%20kraits>
16. Mallow D, Ludwig D, Nilson G (2003). True Vipers: Natural History and Toxinology of Old-World Vipers. Malabar, Florida: Krieger Publishing Company. 359 pp. ISBN 0-89464-877-2.
17. Senji Laxme RR, Khochare S, Attarde S, Suranse V, Iyer A, Casewell NR, Whitaker R, Martin G, Sunagar K. Biogeographic venom variation in Russell's viper (*Daboia russelii*) and the preclinical inefficacy of antivenom therapy in snakebite hotspots. *PLoS Negl Trop Dis*. 2021 Mar 25;15(3):e0009247. doi: 10.1371/journal.pntd.0009247. PMID: 33764996; PMCID: PMC7993602.
18. Saw-scaled viper | snake [Internet]. Encyclopaedia Britannica. Available from: <https://www.britannica.com/animal/saw-scaled-viper>
19. Osipov A, Utkin Y. What Are the Neurotoxins in Hemotoxic Snake Venoms? *Int J Mol Sci*. 2023 Feb 2;24(3):2919. Doi: 10.3390/ijms24032919. PMID: 36769242; PMCID: PMC9917609.
20. David, A., Warrell, 1987. Clinical Features of Snakebite. *The Oxford Textbook of Medicine*, In: 2nd (Eds.); and others, (Eds.), *The Oxford Textbook of Medicine*, pp. 666–677.
21. Mukherjee, P.K. Evaluation of Indian Traditional Medicine. *Ther Innov Regul Sci* 35, 623–632 (2001). <https://doi.org/10.1177/009286150103500235>.
22. Gupta DS. Effective Home Remedies for Swollen Legs [Internet]. PharmEasy Blog. 2022 [cited 2024 Mar 17]. Available from: <https://pharmeasy.in/blog/home-remedies-for-swollen-legs/#:~:text=Certain%20Ayurvedic%20herbs%20are%20used>
23. Sanjay Yadav, Vedpriya Arya, Sandeep Kumar, Manila Yadav and J.P. Yadav. Ethnomedicinal Flora of Dosi Hills of Mahendergarh District (Haryana), India. Department of genetics, Maharshi Dayanand University, Rohtak-124001 (Haryana), India.
24. Bhandary, M.J., Chandrashekar, K.R., Kaveriappa, K.M., 1996. Ethnobotany of Gowlis of Uttara Kannada district, Karnataka. *Journal of Economic and Taxonomic Botany*. 12, 244–249.
25. Ancheril IJ, Sharanesh T, Naveen K, Deepthi V. Snake bite treatment in *Prayoga samuccayam*. *Anc Sci Life*. 2016 Apr-Jun;35(4):245–8. PMCID: PMC4995862.
26. Shwetha Vasudev, Veena S. More, K.S. Ananthraju, Sunil S. More, Potential of herbal cocktail of medicinal plant extracts against 'big four' snake venoms from India, *Journal of Ayurveda and Integrative Medicine*, Volume 12, Issue 3, 2021, Pages 458-464, ISSN 0975-9476, <https://doi.org/10.1016/j.jaim.2021.04.006>.
27. Samy RP, Thwin MM, Gopalakrishnakone P, Ignacimuthu S. Ethnobotanical survey of folk plants for the treatment of snakebites in Southern part of Tamilnadu, India. *J Ethnopharmacol*. 2008 Jan 17;115(2):302-12. DOI: 10.1016/j.jep.2007.10.006. Epub 2007 Oct 10. PMID: 18055146.
28. Dey A, De JN. Traditional use of plants against snakebite in Indian subcontinent: a review of the recent literature. *Afr J Tradit Complement Altern Med*. 2011 Oct 2;9(1):153-74. doi: 10.4314/ajtcam.v9i1.20 . PMID: 23983332; PMCID: PMC3746536.
29. Sharma V, Sharma R, Gautam DS, Kuca K, Nepovimova E, Martins N. Role of Vacha (*Acorus calamus* Linn.) in Neurological and Metabolic Disorders: Evidence from Ethnopharmacology, Phytochemistry, Pharmacology and Clinical Study. *J Clin Med*. 2020 Apr 19;9(4):1176. doi: 10.3390/jcm9041176. PMID: 32325895; PMCID: PMC7230970.
30. Upasani SV, Beldar VG, Tatiya AU, Upasani MS, Surana SJ, Patil DS. Ethnomedicinal plants used for snakebite in India: a brief overview. *Integr Med Res*. 2017 Jun;6(2):114-130. doi: 10.1016/j.imr.2017.03.001. Epub 2017 Mar 20. PMID: 28664135; PMCID: PMC5478250.
31. Manali Sughosh Upasani, Sughosh Vishweshwar Upasani, Vishal Gokul Beldar, Chetana Gokul Beldar, Pranjal P. Gujarathi, Infrequent use of medicinal plants from India in snakebite treatment, *Integrative Medicine Research*, Volume 7, Issue 1, 2018, <https://doi.org/10.1016/j.imr.2017.10.003>.



**Dhivya et al.,**

32. Shen DY, Juang SH, Kuo PC, Huang GJ, Chan YY, Damu AG, Wu TS. Chemical constituents from *Andrographis echinoides* and their anti-inflammatory activity. *Int J Mol Sci.* 2012 Dec 27;14(1):496-514. doi: 10.3390/ijms14010496. PMID: 23271366; PMCID: PMC3565277.
33. Lerma-Herrera MA, Beiza-Granados L, Ochoa-Zarzosa A, López-Meza JE, Navarro-Santos P, Herrera-Bucio R, Aviña-Verduzco J, García-Gutiérrez HA. Biological Activities of Organic Extracts of the Genus *Aristolochia*: A Review from 2005 to 2021. *Molecules.* 2022 Jun 20;27(12):3937. doi: 10.3390/molecules27123937. PMID: 35745061; PMCID: PMC9230106.
34. Saha PS, Sarkar S, Jeyasri R, Muthuramalingam P, Ramesh M, Jha S. In Vitro Propagation, Phytochemical and Neuropharmacological Profiles of *Bacopa monnieri* (L.) Wettst.: A Review. *Plants (Basel).* 2020 Mar 26;9(4):411. doi: 10.3390/plants9040411. PMID: 32224997; PMCID: PMC7238420.
35. Das G, Shin HS, Ningthoujam SS, Talukdar AD, Upadhyaya H, Tundis R, Das SK, Patra JK. Systematics, Phytochemistry, Biological Activities and Health Promoting Effects of the Plants from the Subfamily Bombacoideae (Family Malvaceae). *Plants (Basel).* 2021 Mar 29;10(4):651. doi: 10.3390/plants10040651. PMID: 33805546; PMCID: PMC8067233.
36. Giresha AS, Pramod SN, Sathisha AD, Dharmappa KK. Neutralization of Inflammation by Inhibiting In vitro and In vivo Secretory Phospholipase A2 by Ethanol Extract of *Boerhaavia diffusa* L. *Pharmacognosy Res.* 2017 Apr-Jun;9(2):174-181 doi: 10.4103/0974-8490.204650. PMID: 28539742; PMCID: PMC5424559.
37. Upasani SV, Beldar VG, Tatiya AU, Upasani MS, Surana SJ, Patil DS. Ethnomedicinal plants used for snakebite in India: a brief overview. *Integr Med Res.* 2017 Jun;6(2):114-130. doi: 10.1016/j.imr.2017.03.001. Epub 2017 Mar 20. PMID: 28664135; PMCID: PMC5478250.
38. Upasani SV, Beldar VG, Tatiya AU, Upasani MS, Surana SJ, Patil DS. Ethnomedicinal plants used for snakebite in India: a brief overview. *Integr Med Res.* 2017 Jun;6(2):114-130. doi: 10.1016/j.imr.2017.03.001. Epub 2017 Mar 20. PMID: 28664135; PMCID: PMC5478250.
39. Deshpande AM, Sastry KV, Bhise SB. A Contemporary Exploration of Traditional Indian Snake Envenomation Therapies. *Trop Med Infect Dis.* 2022 Jun 16;7(6):108. doi: 10.3390/tropicalmed7060108. PMID: 35736986; PMCID: PMC9227218.
40. Fatmawati S, Yuliana, Purnomo AS, Abu Bakar MF. Chemical constituents, usage and pharmacological activity of *Cassia alata*. *Heliyon.* 2020 Jul 11;6(7): e04396. doi: 10.1016/j.heliyon.2020.e04396. PMID: 32685725; PMCID: PMC7358271.
41. Samanta J, Bhattacharya S, Rayat R. Phytochemical investigation and pharmacognostic standardization of *Cissampelos pareira* root. *Anc Sci Life.* 2012 Apr;31(4):181-4. doi: 10.4103/0257-7941.107352. PMID: 23661865; PMCID: PMC3644755.
42. Mukherjee PK, Kumar V, Kumar NS, Heinrich M. The Ayurvedic medicine *Clitoria ternatea*—from traditional use to scientific assessment. *J Ethnopharmacol.* 2008 Dec 8;120(3):291-301. doi: 10.1016/j.jep.2008.09.009. Epub 2008 Sep 20. PMID: 18926895.
43. Aiswarya SUD, Vikas G, Haritha NH, Liju VB, Shabna A, Swetha M, Rayginia TP, Keerthana CK, Nath LR, Reshma MV, Sundaram S, Anto NP, Lankalapalli RS, Anto RJ, Bava SV. Cucurbitacin B, Purified and Characterized From the Rhizome of *Corallocarpus epigaeus* Exhibits Anti-Melanoma Potential. *Front Oncol.* 2022 Jun 8; 12:903832. doi: 10.3389/fonc.2022.903832. Erratum in: *Front Oncol.* 2022 Aug 12; 12:989283. PMID: 35756619; PMCID: PMC9213886.
44. Wang, Y.; Li, J.; Li, N. Phytochemistry and Pharmacological Activity of Plants of Genus *Curculigo*: An Updated Review Since 2013. *Molecules* 2021, 26, 3396. <https://doi.org/10.3390/molecules26113396>
45. Jana S, Shekhawat GS. Critical review on medicinally potent plant species: *Gloriosa superba*. *Fitoterapia.* 2011 Apr;82(3):293-301. doi: 10.1016/j.fitote.2010.11.008. Epub 2010 Nov 6. PMID: 21059382.
46. Kini, R. M. and Gowda, T. V., 1983, 2900012, English, Journal article, 19, (2), Indian Journal of Biochemistry & Biophysics, (152–154), Studies on snake venom enzymes: Part I -purification of ATPase, a toxic component of *Naja naja* venom and its inhibition by potassium gymemate.
47. M.I. Alam, B. Auddy, A. Gomes, Isolation, purification and partial characterization of viper venom inhibiting factor from the root extract of the Indian medicinal plant *sarsaparilla* (*Hemidesmus indicus* R.Br.), *Toxicon*,





Dhivya et al.,

- Volume 32, Issue 12, 1994, Pages 1551-1557, ISSN 0041-0101, [https://doi.org/10.1016/0041-0101\(94\)90314-X](https://doi.org/10.1016/0041-0101(94)90314-X). (<https://www.sciencedirect.com/science/article/pii/004101019490314X>)
48. Upasani SV, Beldar VG, Tatiya AU, Upasani MS, Surana SJ, Patil DS. Ethnomedicinal plants used for snakebite in India: a brief overview. *Integr Med Res.* 2017 Jun;6(2):114-130. doi: 10.1016/j.imr.2017.03.001. Epub 2017 Mar 20. PMID: 28664135; PMCID: PMC5478250.
 49. Adeyi AO, Ajisebiola BS, Adeyi OE, Alimba GC, Okorie UG (2020) Antivenom activity of Moringa oleifera leave against pathophysiological alterations, somatic mutation and biological activities of Naja nigricollis venom. *Sci Afr* 8:e00356. <https://doi.org/10.1016/j.sciaf.2020.e00356>
 50. Pushpangadan, P.; Kaur, Jeet; Sharma, Jyoti. PLANTAIN OR EDIBLE BANANA (MUSA X PARADISICA VAR – SAPIEMTUM) SOME LESSER KNOWN FOLK USES IN INDIA. *Ancient Science of Life* 9(1):p 20-24, Jul-Sep 1989.
 51. Mohammad Fahim Kadir, James Regun Karmoker, Md. Rashedul Alam, Syeda Rawnak Jahan, Sami Mahbub, M. M. K. Mia, "Ethnopharmacological Survey of Medicinal Plants Used by Traditional Healers and Indigenous People in Chittagong Hill Tracts, Bangladesh, for the Treatment of Snakebite", *Evidence-Based Complementary and Alternative Medicine*, vol. 2015, Article ID 871675, 23 pages, 2015. <https://doi.org/10.1155/2015/871675>.
 52. Md. Nazmul Hasan, Nur Kabidul Azam, Md. Nasir Ahmed, Akinori Hirashima, A randomized ethnomedicinal survey of snakebite treatment in southwestern parts of Bangladesh, *Journal of Traditional and Complementary Medicine*, Volume 6, Issue 4, 2016, Pages 337-342, ISSN 2225-4110, <https://doi.org/10.1016/j.jtcme.2015.03.007>. (<https://www.sciencedirect.com/science/article/pii/S2225411015000462>)
 53. Gomes, A Antisnake venom activity of ethanolic seed extract of Strychnos nux vomica Linn. *NISCAIR-CSIR, India*. May-2004IPC Code: Int. Cl.7 A61K
 54. Shabana Kusar, Zeb Saddiqe, Muhammad Hassam Hassan Bin Asad, Faiza Ali, Fatima Kirmani, Phytochemical characterization and phospholipase A2 inhibitory effect of Vitex negundo L. root extracts, *Journal of Ethnopharmacology*, Volume 323, 2024, 117671, ISSN 0378-8741, <https://doi.org/10.1016/j.jep.2023.117671>. (<https://www.sciencedirect.com/science/article/pii/S0378874123015416>)
 55. Juliana Félix-Silva, Arnóbio Antônio Silva-Junior, Silvana Maria Zucolotto, Matheus de Freitas Fernandes-Pedrosa, "Medicinal Plants for the Treatment of Local Tissue Damage Induced by Snake Venoms: An Overview from Traditional Use to Pharmacological Evidence", *Evidence-Based Complementary and Alternative Medicine*, vol. 2017, Article ID 5748256, 52 pages, 2017. <https://doi.org/10.1155/2017/5748256>.
 56. Deshpande AM, Sastry KV, Bhise SB. A Contemporary Exploration of Traditional Indian Snake Envenomation Therapies. *Trop Med Infect Dis.* 2022 Jun 16;7(6):108. doi: 10.3390/tropicalmed7060108. PMID: 35736986; PMCID: PMC9227218.
 57. Dias da Silva W, De Andrade SA, Megale ÁAA, De Souza DA, Sant'Anna OA, Magnoli FC, Guidolin FR, Godoi KS, Saladini LY, Spencer PJ, Portaro FCV. Antibodies as Snakebite Antivenoms: Past and Future. *Toxins (Basel)*. 2022 Sep 1;14(9):606. doi: 10.3390/toxins14090606. PMID: 36136544; PMCID: PMC9503307.

Table 1. List of medicinal herbs used for snake bite envenomation:

S.NO	NAME OF THE PLANT	FAMILY	PART OF THE MEDICINAL PLANT SUBSTANCE USED	REFERENCE
1	<i>Abrus precatorius</i> Linn	Fabaceae	Seed, leaf, root	27
2	<i>Achyranthes aspera</i> Linn	Amaranthaceae	Root, seed, leaf, stem and whole plant	28
3	<i>Acorus calamus</i> Linn	Araceae	Rhizome	29





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4	<i>Alangium salvoifolium</i> Linn	Alangiaceae	Root, leaf, stem bark, whole plant	30
5	<i>Albizia lebeck</i> Linn	Fabaceae	Leaves, bark, flower, whole plant, root	31
6	<i>Andrographis echioides</i> Nees	Acanthaceae	Whole plant	32
7	<i>Aristolochia Bracteolata</i> Lamk	Aristolochiaceae	Leaves, root	33
8	<i>Bacopa monnieri</i> Linn	Scrophulariaceae	Bark, leaf, whole plant	34
9	<i>Bombax ceiba</i> Linn	Bombaceae	Flowers, roots, bark, seed	35
10	<i>Boerhaavia diffusa</i> Linn	Nyctaginaceae	Leaf, whole plant	36
11	<i>Buchanania lanzan</i> Spr	Anacardiaceae	Bark	37
12	<i>Butea monosperma</i> Taub	Fabaceae	Bark, leaf, flower, gum, seed, stem, resin, latex	38
13	<i>Calotropis gigantea</i> Linn	Apocynaceae	Roots, bark	39
14	<i>Cassia alata</i> Linn	Caesalpiaceae	Leaf	40
15	<i>Cissampelos pareira</i> Linn	Menispermaceae	Tuber, root	41
16	<i>Clitoria ternatea</i> Linn	Fabaceae	Roots	42
17	<i>Corallocarpus epigaeus</i> Hook.f.	Cucurbitaceae	Root, tuber	43
18	<i>Curculigoorchioide</i> Gaertn	Amaryllidaceae	Root, tuber	44
19	<i>Gloriosa superba</i> Linn	Liliaceae	Tuber, root, rhizome, seed	45
20	<i>Gymnema sylvestre</i> (Retz.) R.Br.	Asclepiadaceae	Leaf, root	46
21	<i>Hemidesmus indicus</i> (Linn)	Apocynaceae	Root, leaf	47
22	<i>Mimosa pudica</i> Linn	Mimosaceae	Root, leaf, whole plant	48
23	<i>Moringa oleifera</i> Linn	Moringaceae	Root, seed, whole plant, stem bark, leaf	49
24	<i>Musa paradisiaca</i> Linn	Musaceae	Bark, stem, skin bark	50
25	<i>Piper nigrum</i> Linn	Piperaceae	Flower, seed, fruit	51
26	<i>Rauwolfia serpentina</i> Linn	Apocynaceae	Leaf, root	52
27	<i>Strychnos vomica</i> Linn	Loganiaceae	Root, seed	53
28	<i>Vitex negundo</i> Linn	Verbenaceae	Bark, root, seed, leaf	54
29	<i>Leucas cephalotes</i> (Roth) Spreng	Lamiaceae	Whole plant	55

Table 2. Significantly related studies supporting evidences of the review.

S.NO	NAME OF THE AUTHOR	TITLE OF THE STUDY	PUBLICATION YEAR	INFERENCE
1	Protha Biswas, Mimosa Ghorai, Tulika Mishra, Abilash, Valsala Gopalakrishnan, Debleena	<i>Piper longum</i> L.: A comprehensive review on traditional uses, phytochemistry,	2022 Oct	Examining <i>P. longum</i> 's habitat, distribution, ethnobotany, phytochemistry, and





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	Roy, Abhijit Bhagwan Mane, Avinash Mundhra, Neela Das, Vikas Moreshwar Mohture, Manoj Tukaram Patil, Md Habiburnrahman, Niraj Kumar Jha, Gaber El-Saber Batiha, Suchismita Chatterjee Saha, Mahipal S, Shekhawat, Radha, Manoj Kumar, Devendra Kumar Pandey, Abhijit Dey	pharmacology, and health- promoting activities		pharmacology in detail, this paper confirms the plant's medicinal value and health benefits via scientific research.
2	Itta Krishna Chaaithanya, Dipak Abnav, Himmatro Bawaskar, Ujwal Pachalkar, Sandip Tarukar, Neha Salvi, Prabhakar Bhoje, Arun Yadav, Smita D Mahale, Rahul K Gajbhiye	Perception, awareness on snakebite envenoming among the tribal community and health care providers of Dahanu block, Palghar District in Maharashtra, India	2021 Aug	This study investigates the potentially risky and high-mortality untested and harmful snakebite treatment practices used by the peoples of a tribal block in Dahanu, Maharashtra, India.
3	Shwetha Vasudev, Veena S.More, K.S. Ananthraju, Sunil S. More	Potential of herbal cocktail of medicinal plant extracts against 'big four' snake venoms from India	2021 July–September	It has been demonstrated that polyherbal formulations work better than single formulations to treat snake bites. In ex vivo and in vivo models, tests for antidote capability against BIG FOUR venoms were conducted using <i>Azadirachata indica</i> , <i>Butea monosperma</i> , <i>Citrus limon</i> , <i>Clerodendrum serratum</i> , and <i>Areca catechu</i> . The results showed that this cocktail neutralized their venom.
4	Akshatha Ganesh Nayak1. Nitesh Kumar2. Smita Shenoy3. Maya Roche1	Evaluation of the merit of the methanolic extract of <i>Andrographis paniculata</i> to supplement anti – snake venom in reversing secondary hemostatic abnormalities induced by naja naja venom	2021 April	This study assessed the effectiveness of ASV, MAP, and their combination in reversing the haemostatic abnormalities caused by NN venom. The Indian polyvalent ASV successfully reversed the adverse effects of the venom on clotting pathways.
5	Akindele Oluwatosin Adeyi Phd A, Siji Babafemi Ajisebiola B, Esther Olubisi Adeyi C, Chibuisi Gideon Alimba Ph.D D, Uchennaya	Antivenom activity of <i>Moringa oleifera</i> leave against pathophysiological alteration, somatic	2020 July	This study has shown that <i>M. oleifera</i> has antivenom properties and is traditionally used in the treatment of snakebites.





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	Godwill Okorie A	mutation and biological activities of <i>Naja nigricollis</i> venom		
6	Samapika Nandy, Anuradha Mukherjee, Devendra Kumar Pandey, Puja Ray, Abhijit Dey	Indian Sarsaparilla (<i>Hemidesmus indicus</i>): Recent progress in research on ethnobotany, phytochemistry and pharmacology	2020 Jan	The study highlights the diverse pharmacological activities of <i>H. indicus</i> but emphasizes the need for further research to identify active phytoconstituents and understand their structure-activity relationship.
7	P. Kannan and Santhosh Kumar	Antidotes against snakebite from Ethnobotanical practices of primitive tribes of Tamil Nadu	2018 August	This study brought to light the immense knowledge of tribal people about antidote plants used against snake bites.
8	Juliana Felix-Silva, 1 Arnobio Antonio Silva-Junior, 1 Silvana Maria Zucolotta 2 And Matheus De Freitas Fernandes-Pedrosa	Medical plants for the Treatment of Local Tissue Damage Induce by Snake Venoms: An Overview from Traditional Use to Pharmacological Evidence	2017 August	This study offers an updated analysis as well as suggestions for further studies to confirm the safety of therapeutic herbs as antivenomants.
9	Sughosh V. Upasani A, Vishal G. Beldar B, Anil U. Tatiya B, M.S Upasani C, Sanjay J. Surana B, Divyata S. Patil B	Ethnomedicinal plants used for snakebite in India: a brief overview	2017 June	The data collection for the most often used herbs in the treatment of snakebite was the main focus of this research.
10	Niyati Acharya, Sanjeev Acharya, Unnati Shah, Ripal Shah Lal Hingorani.	A comprehensive analysis on <i>Symplocos racemose</i> Roxb, Traditional uses, botony, phytochemistry and pharmacological activities	2016 Feb	Ethnobotanical studies highlight the use of traditional plants to treat various diseases; however, further research is needed to prove their efficacy.
11	P.D Chaudhari P.A Shenoy S.S. Nipate J.M. Sonpetkar N.C. Salvi A.B. Waghmare	Anti – snake venom activities of ethanolic extract of fruits of <i>Piper longum</i> L. (Piperaceae) against Russell's viper venom: Characterization of piperine as active principle	2013 May	This study reveals that Piperine, found in PLE, contributes to its effective and good anti-snake venom properties.
12	Payel Bhattacharjee, Debasish Bhattacharyya	Characterization of the aqueous extract of the root of <i>Aristolochia indica</i> : Evaluation of its	2013 January	This study supports the traditional use of an aqueous extract of <i>Aristolochia indica</i> root as a remedy for Russell's





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		traditional use an antidote for snake bites		viper envenomation.
13	Y. K Gupta And S.Peshin	Do Herbal Medicines Have Potential for Managing Snake Bite Envenomation?	2012 May-Aug	Herbal remedies for snake venom appear to be a good substitute. In traditional medicine, only a few species are thought to be beneficial for treating snake bites.
14	Ipshita Chatterjee, A K Chakravarty, A Gomes	Antisnake venom activity of ethanolic seed extract of <i>Strychnos nux vomica</i> Linn	2004 May	The whole seed extract of <i>S. nux vomica</i> was able to counteract the neurotoxic and cardiotoxic venom of <i>Naja naja</i> as well as the deadly hemorrhage caused by <i>Daboia russelii</i> venom.
15	Monimala Mahanta, Ashis Kumar, Mukherjee	Neutralization of lethality, myotoxicity and toxic enzymes of <i>Naja kaouthia</i> venom by <i>Mimosa pudica</i> root extracts	2001 April	The in vitro and in vivo studies of effectiveness of anti-venom properties of roots of <i>M.Pudica</i> was studied. It was found to neutralize cobra venom

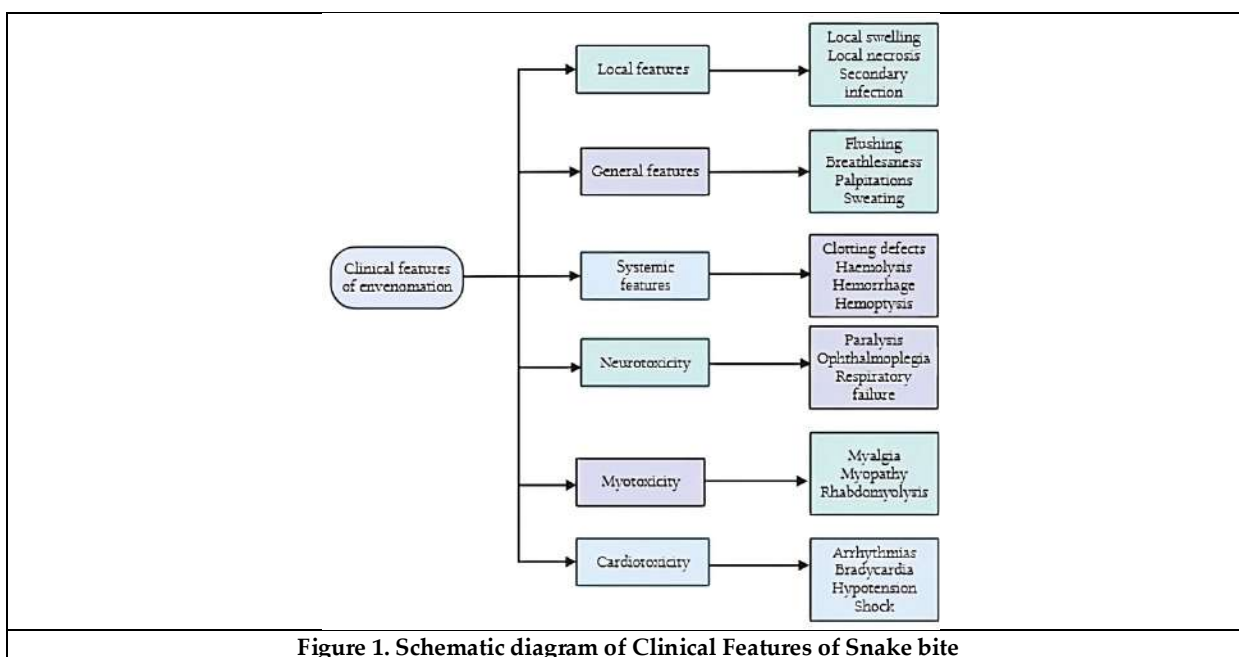


Figure 1. Schematic diagram of Clinical Features of Snake bite





Fuel Characterization and Kinetic Study of Sugarcane Bagasse Briquette for Power Generation

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ABSTRACT

Briquettes made from Sugarcane Bagasse have emerged as an alternative energy source for fuel production. The main ingredients of the selected biomass briquette are Sugarcane Bagasse (agricultural waste) with molasses and clay as a binder in the formulation of 1:2:20 respectively. The results of the physicochemical analysis reveal that the selected Sugarcane Bagasse Briquette (SBB) has low moisture (10.5), high volatile matter (74.8), low ash content (5.13) and high calorific value (18.6 MJ/Kg). The thermal degradation of SBB is found using thermogravimetric analysis at a heating rate of 20°C/min. The result shows that a maximum mass loss of 53.04% occurs at a temperature of 350°C. The activation energy needed for thermal degradation is estimated using the Coats-Redfern method and it is found to be 103.12 KJ/mol. The FT-IR and EDAX analyses reveal that SBB has a higher proportion of hydrocarbons and trace quantities of SO_x and NO_x . After characterization, the SBB is fed into a 5kW/h downdraft biomass gasifier and the thermal efficiency is obtained as 79.9%. Thus, the results confirmed that SBB satisfies all the combustion process requirements in an eco-friendly manner and provides a new perspective to investigate other agricultural wastes for the need of energy resources for power generation.

Keywords: Sugarcane Bagasse, Briquette, Calorific value, Activation energy, Thermal efficiency.





INTRODUCTION

At present, the major energy contributors; fossil fuels such as coal, petroleum etc., are going to be depleted soon. Also, the increase in prices of fossil fuels and facing a serious problem of environmental degradation, forced us to rely on another alternative resource for energy. Biomass is one of the largest energy sources in the world and contributes about half of the global energy consumption among Renewable Energy Sources (19%) [1]. Among biomass materials, the energy produced from wastes should become a promising outlook for a sustainable environment. The majority of biomass wastes contain higher moisture content, irregular shape, low bulk density and low energy content [2]. These wastes cannot be used as fuel without appropriate processing techniques. Therefore, a processed and well-defined form of biomass waste can be used as a feedstock for energy purposes. To overcome this obstacle, it is necessary to convert these biomass wastes to a well-known technique called Briquetting. Briquetting is one of the densifying methods for the compaction of agricultural wastes into solid fuel[3]. Agricultural residues such as rice husk, sawdust, peanut shell, pistachio shell, corn straw, palm kernel shell and bagasse play a major role in briquette production. Literatures also revealed that Sugarcane bagasse – an agricultural residue can be used as feedstock for energy production [4]. Briquettes made by Olugbade and Mohammed [5] exhibited a higher heating value because of the property of the binding agent – cassava starch added. Molasses can be used as a binder for briquetting and pelleting of biomass materials [6]. By increasing the binders' compacting pressure and processing temperature, the density and energy content per unit volume of fuel briquettes will be increased [7]. Thus, binders significantly influence briquette quality and properties [8]. The present work primarily aims to examine the physicochemical analysis of Sugarcane Bagasse Briquette (SBB) with molasses and clay as binders. In addition, the spectral (FT-IR, EDAX) analysis and thermal degradation behaviour (TG-DTG analysis) were performed for a better insight into the visualization of SBB's fuel properties. The thermal efficiency of SBB was found by feeding it in a 5 kW/h downdraft gasifier. This study will enhance the future scope for using agricultural residues (briquette form) as a fuel for power generation.

MATERIALS AND METHODS

Sugarcane Bagasse was selected as a feedstock for this study. The bagasse was moulded in a briquette form, using molasses and clay as a binder. The ratio of the formulation of this briquette was 1:2:20 (molasses, clay and carbonized bagasse) respectively. Each briquette was made with approximately a diameter of 7.1 cm (Fig. 1). The briquette was sundried for about 20 - 30 days. The prepared briquette was sealed in a polythene bag for the further combustion process. The dried sample was ground into powdered form for characteristics analysis.

PHYSICAL PROPERTIES CHARACTERIZATION

BULK DENSITY

Bulk density was measured using a container of known volume, V . Initially, the mass of the briquette with the container was measured, it gives M . Then the bulk density of the briquette was calculated by,

$$\text{Bulk density} = \frac{\text{Mass of biomass sample taken in the container (kg)}}{\text{Volume of measuring container (m}^3\text{)}} \quad (\text{kg/m}^3) \quad (1)$$

DURABILITY

A drop test was done to investigate the durability of the briquette. The bagasse briquette was dropped at a height of 2 m, then the mass loss was measured. The durability was determined by,

$$\text{Durability} = \frac{\text{Mass of briquette after drop test}}{\text{Mass of briquette before drop test}} \quad (2)$$

This durability test was essential, in determining the quality and handling of briquettes in terms of storage, transportation and operation. [9]





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SHATTER INDEX

The hardness of the briquette was investigated by shatter index. The briquette (SBB) was repeatedly dropped from an extent of 1 m onto a reinforced floor [10]. The deformed briquette of known weight was measured. Using equations (3) and (4), the shatter resistance was calculated [10].

$$WL = \frac{W_1 - W_2}{W_1} \times 100 \quad (3)$$

where: WL = weight loss (%)

W_1 = weight of briquette before shattering (g)

W_2 = weight of briquette after shattering (g)

$$\text{Shatter resistance} = 100 - WL(\%) \quad (4)$$

WATER RESISTANCE

The water resistance of Sugarcane Bagasse Briquette (SBB) was tested to check whether it can withstand rainy seasons and cold weather. As proposed by Tayade 2009 [12], the weight absorbed and the water resistance of SBB was given by the formula (5) and (6),

$$WA = \frac{W_2 - W_1}{W_2} \times 100 \quad (5)$$

where: WA = weight absorbed by the briquette (%)

W_1 = initial weight of the briquette (g)

W_2 = final weight of the briquette (g)

$$\text{Water resistance} = 100 - WA (\%) \quad (6)$$

CHEMICAL PROPERTIES CHARACTERIZATION

PROXIMATE AND ULTIMATE ANALYSIS

The proximate analysis was mainly used to determine the calorific value (heating value of the fuel), ash content, fixed carbon, volatile matter and moisture content. The experimental calorific value of the SBB was calculated using an RSBT -5 model bomb calorimeter in accordance with the ASTM standard D5865-13 [13]. The proximate analysis was performed by weight method using a hot air oven and muffle furnace. The total contents of Carbon, Hydrogen, Nitrogen and Sulphur present in SBB were determined using ELEMENTAR Vario EL III – CHNS analyser (SAIF Cochin).

SPECTRAL ANALYSIS

FTIR analysis is the most significant analytical tool for the fast characterization of biomass samples containing lignocellulose compounds [14]. The SBB was subjected to FTIR spectra within the wave number of 400 to 4000 cm^{-1} . The minor elements in the sample were pinpointed using Jeol 6390LA/ OXFORD XMX N type elemental analyser(EDAX analysis)

THERMOGRAVIMETRIC ANALYSIS

The thermal behaviour of the selected briquette was studied under a constant heating rate of 20 $^{\circ}$ C / min in a constant nitrogen atmosphere using A Jeol 6390LA/ OXFORD XMXN TG – DTG analyser.

COMBUSTION CHARACTERISTIC PARAMETERS

The combustion characteristics parameters include ignition temperature (T_i), peak temperature (T_p), burnout temperature (T_b), maximum decomposition rate (%/min), average burning rate (%/min) and Combustion characteristic index (S_N). The ignition temperature (T_i), peak temperature (T_p), burnout temperature (T_b) and maximum decomposition rate (%/min) can be directly obtained from TG-DTG curves. The average burning rate is calculated from the below equation used by Jianbiao Liu et al 2021[15]

$$\left(\frac{d\alpha}{dt}\right) = \beta X \frac{\alpha_i - \alpha_f}{T_f - T_i} \quad (7)$$

where β refers to heating rate in $^{\circ}\text{C}/\text{min}$, α_i is the percentage mass of the sample during ignition temperature, α_f denotes the percentage mass of the sample with respect to the burnout temperature. The Combustion characteristic index, (S_N) is found by using the equation reported by Lei Tang et al 2022[16],





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$$S_N = \frac{\left(\frac{d\alpha}{dt}\right)_{mean} \left(\frac{d\alpha}{dt}\right)_{max}}{T_i^2 T_f} (8)$$

where $\left(\frac{d\alpha}{dt}\right)_{mean}$ is the average burning rate of the sample in %/min, $\left(\frac{d\alpha}{dt}\right)_{max}$ is the maximum decomposition rate in %/min.

KINETIC STUDY

The pyrolysis process of biomass conversion in a single reaction includes biochar and volatiles where volatiles include syngas and tar. Using the basic kinetic equation (9), reported by Lei Tang et al., 2022[16] the activation energy of SBB can be calculated.

$$\ln\left[\frac{-\log(1-\alpha)}{T^2}\right] = -\frac{E}{RT} + \ln\left[\frac{AR}{\beta T}\left(1 - \frac{2RT}{E}\right)\right] \quad (9)$$

$$g(\alpha) = -\frac{E}{RT} + \ln\left[\frac{AR}{\beta T}\left(1 - \frac{2RT}{E}\right)\right] \quad (10)$$

where

$$g(\alpha) = \ln\left[\frac{-\log(1-\alpha)}{T^2}\right]$$

A slope of $-E/R$ is obtained by plotting $g(\alpha)$ in Y ordinate and $1/T$ in X ordinate

By plotting $g(\alpha)$ in Y ordinate and $1/T$ in X ordinate gives a slope value of $-E/R$. This provides the activation energy of the sample at a desired decomposition stage.

BIOMASS GASIFICATION IN A 5kW/h DOWNDRAFT BIOMASS GASIFIER

Gasification is a thermochemical process in which the hydrocarbon materials (biomass, coal etc.) is converted into synthesis gas (producer gas) through partial oxidation with air, oxygen, steam and/or supercritical water [17]. In this 5 kW/h downdraft gasifier, the air is used as an oxidising agent, this choice of gasifying agent governs the composition of the producer gas and its calorific value desired [18]. In the drying phase, the dehydration of the sample will take place, and the temperature of the drying zone is about 70-200⁰ C. In the pyrolysis phase, the volatile matter is removed from SBB which is mainly composed of hydrocarbons. These volatiles lead to the formation of tar. The temperature of this phase is about 350-500⁰ C. In the combustion zone, the partial mass of the biomass sample gets combusted, with a maximum temperature up to 1200⁰ C. In the reduction zone, the producer gas leaves the gasifier with a temperature between 200-300⁰ C. The outgoing gas is composed of tar, dust and water vapour which was removed by proper filters. The thermal efficiency was calculated by using the formula,

$$\text{Thermal Efficiency, } \eta_g = \left(\frac{\text{Heating value of gas}}{\text{Heating value of fuel wood}}\right) \left(\frac{\text{Gas flow rate}}{\text{Fuel consumption rate}}\right) \quad (11)$$

where, heating value of fuel wood was calculated using bomb calorimeter,

$$\left(\frac{\text{Gas flow rate}}{\text{Fuel consumption rate}}\right) \text{ was } 2.91 \text{ kg/m}^3 [19] \quad (12)$$

RESULTS AND DISCUSSIONS

PHYSICAL PROPERTIES ANALYSES OF SBB

BULK DENSITY

Bulk density is an important physical parameter in briquetting [20] since it directly affects the storage requirements and cost of transportation [21]. The bulk density of the SBB was found to be 630 kg/m³. Greater the bulk density, the longer the effect on the combustion time of the briquettes[22] and the obtained bulk density of SBB (630 kg/m³) was in the recommended range 285–964 kg/m³ for briquette [9].

DURABILITY

The durability of the SBB was calculated as 0.996 (equation 2). As suggested by Tabil.L and Sokhansanj [23], durability was classified into high (greater than 0.8), medium (0.7-0.8), and low (less than 0.7). Therefore, the sample



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considered for this study (SBB) has highest durability. This high durability leads to fuel application[24]. Similar findings were observed for Cotton stalk briquettes which has a durability of 0.97 [9].

SHATTER INDEX

The weight loss of the SBB was observed as 0.311 (equation 3). The significant shatter resistance was calculated as 99.688% (equation 4). This high shatter resistance is due to the high binding ability of molasses and clay[25]. This result indicates that the considered SBB was more durable and had resistant to handling stresses in long-distance transportation [26].

WATER RESISTANCE

The obtained water resistance for the selected sample was 97.27%. Briquettes with water resistance greater than 95% should be recommended for storage purposes [27]. This result shows that the considered SBB was easy to store even in cold weather.

PHYSICO-CHEMICAL ANALYSIS OF SBB

PROXIMATE ANALYSIS

Proximate analysis is an important tool to study the combustion characteristics of biomass material. Table 2 shows the proximate analysis of the SBB. Since the moisture content of SBB was calculated as 10.5% which was in the recommended range[28], the selected biomass briquette having this moisture content(10.5%) can be recommended as a quality one. Generally, the ash content of the densified biomass was curtailed than that of the coal values [29]. The low ash content value (5.13%) was noticed and this promotes the better combustion process of SBB effectively also increases the rate of devolatilization during pyrolysis [30]. The volatile matter obtained for SBB (74.8%) was suitable for pyrolysis and promotes better volatilization than other types of briquettes such as Saw dust (73.74%), Peanut shell (68.1%) and Rice straw (64.44%)[4,31]. As reported by lenadzifa Mensah 2017[32], the fixed carbon content of SBB was relatively low (9.5%) when comparing it with that of charcoal because of the cellulose, hemicellulose and lignin constituents of biomass. The binding agent and best durability give significantly a higher heating value [33]. The higher heating value of biomass materials is advisable for thermal purposes. The calorific value of SBB was experimentally calculated as 18.6 MJ/kg which was greater than the calorific value of recommended range for the briquette as prescribed by N.S.L. Srivastava, 2014 [34]. Thus, the Sugarcane Bagasse Briquette can be considered as the best fuel for energy purpose. Also, the experimentally obtained calorific value was in agreement with the theoretically obtained higher heating value as suggested by Parikh et al., 2005 [35]. The theoretically obtained HHV was 16.57 MJ/kg. The difference between the theoretically calculated and experimentally obtained HHV was ~ 2.03.

ULTIMATE ANALYSIS

The main elements of the SBB are Carbon, Hydrogen, Nitrogen, Sulphur and Oxygen in a weight percentage of 65.90, 11.91, 0.04, 0.03 and 32.19 respectively. The high amount of Carbon and Hydrogen (Carbon – 65.90% and Hydrogen – 11.91%) in SBB promotes higher heating value (HHV) index [36]. The higher Oxygen content (32.19) present in SBB was similar in case of corn straw briquette [15]. Also, the trace quantities of Nitrogen and Sulphur (0.04 and 0.03) have a positive approach towards the emission of greenhouse gases. Generally, the presence of Nitrogen and Sulphur in biomass raises the greenhouse effect, leads to climatic change and is also responsible for the emissions of NO_x and SO_x[37]. The Low Nitrogen and Sulphur content in SBB shows that it is an ideal source for energy production with an eco-friendly manner. The Hydrogen to Carbon ratio and Oxygen to Carbon ratio was 0.18 and 0.48 respectively. It is evident that lower ratios of H/C and O/C lead to a higher heating value of the fuel material [29]. Also, the C/N ratio was high (1647) implying that the sample is most suitable for thermochemical conversion processes [37]. The prediction of the empirical formula was crucial while predicting the by-products obtained in the pyrolysis process [38]. The empirical formula for SBB was found to be CH_{0.18} O_{0.48} N_{0.03}. The elemental composition of SBB is given in Fig. 2





FT-IR ANALYSIS

FT-IR Analysis was performed to confirm the functional groups present in the selected briquette [39]. FT-IR spectra of selected SBB was given in Fig. 3. Peak at 3419 cm^{-1} confirms the O-H stretching intramolecular H-bonds [40]. The Peak at 2926 cm^{-1} indicates both symmetric and asymmetric stretching of the axial deformation of the C-H aliphatic in the CH_2 and CH_3 groups of Cellulose, Hemicellulose and Lignin. These carboxylic and hydroxyl groups are responsible for the high volatility of the sample [41]. The region from 1800 cm^{-1} to 650 cm^{-1} is the **Fingerprint region**, this region is mostly crowded with peaks this complexity makes this region as a unique pattern for identifying each molecule. According to the literature the bands at 1247 cm^{-1} , 1460 cm^{-1} , 1510 cm^{-1} have been associated with lignin [42]. The presence of hemicellulose is responsible for the peak at 1713 cm^{-1} which is attributed to C=O stretching vibration. Peaks at 1609 cm^{-1} and 1510 cm^{-1} are due to C=C ring stretching and the Phenolic Hydroxyl group (O-H) due to the existence of water molecules present in the sample [43]. The Peak at 1460 cm^{-1} is due to the symmetric distortion of CH_2 group of lignin [44]. The peaks at 1247 cm^{-1} and 1037 cm^{-1} are due to the occurrence of C-O-C in Hemicellulose and lignin [45]. Similar spectra were obtained in analogous to the FT-IR spectra of pistachio shells, corn stalks and pine sawdust [46].

EDAX ANALYSIS

The EDAX Analysis gives information about the elements present in the selected biomass material. The major elements are Carbon (62.71%) and Oxygen (37.1%) and the remaining elements Silicon (0.14%) and Chlorine (0.05%) are in trace quantities (Table 4). High carbon (62.71%) and oxygen (37.1%) content will increase the calorific value of the biomass [47]. Literature says that Sugarcane Bagasse and wheat husk are advantageous for environmental anxieties because they are not release any of the toxic and harmful gases such as Sox and NOx [48].

THERMOGRAVIMETRIC ANALYSIS

Figure 4 shows thermogravimetric and derivative thermogravimetric curves at a heating rate of $20^\circ\text{C min}^{-1}$. The combustion characteristics parameters are tabulated in Table 5. The whole thermal degradation process occurs in three stages viz., Dehydration stage, Active pyrolysis stage (ignition phase) and Passive pyrolysis stage. In the first stage namely dehydration stage, water content present in the sample gets removed along with some of the volatile matters [49] with a mass loss of 6.92% within the temperature range 50°C – 245.2°C and also a smaller peak is recognized. After the dehydration stage, the sample begins to combust at a temperature of 245.2°C which is called Ignition temperature (T_i). In the active pyrolysis stage, the combustion process gets rapidly increases with increase in temperature. This stage begins at 245.2°C and ends at 360.6°C . The mass loss (53.04%) occurred at 329.2°C which is called Peak temperature (T_p). This stage is considered as a main reaction stage since the major components such as hemicellulose, cellulose in the biomass sample gets decomposed leads to the combustion of volatile matters [50]. The last stage is referred as the passive pyrolysis stage starts at 360.6°C and ends at burnout temperature, $T_f = 468^\circ\text{C}$ with a comparable mass loss of 15.36%. This mass loss is related to the char burning once the sample has devolatilized. The residual mass percentage of the sample after complete combustion is noted as 1.34%. These thermal analysis findings were consistent with the research conducted by Ahmed et al. 2017 [51] and Braga et al. 2004 [52] in the case of elephant grass biomass and Eulaliopsis binata respectively. The combustion characteristics parameters are tabulated in Table 5. Higher the value of combustion characteristic index ($S_{NX} 10^{-7}$) yields higher combustion activity as reported by Joanna Wnorowska et al., 2021 [53]. The kinetic behaviour of the selected sample (SBB) is studied using Coats-Redfern method. This method is a suitable technique to study the kinetic parameters since it uses constant heating rate [54]. The Activation energy estimated for SBB using this method is 103.12 kJ/mol in the active pyrolysis region 244°C to 360°C . The combustion parameters give good correlation and Regression factor. Better estimation is indicated by a higher Regression factor ($R^2=1$) [55]. This high value of Regression factor ($R^2=0.88$) indicates that the selected Coats-Redfern method is more reliable and suited to this experimental analysis [56].

BIOMASS GASIFICATION AND PERFORMANCE PARAMETERS FOR SBB

The Calorific value of the Sugarcane Bagasse Briquette (SBB) was observed as 18.6 MJ/Kg which is a higher calorific value among the agricultural residue briquettes such as Rice husk (13.38 MJ/Kg) and Paddy straw (14.51 MJ/Kg) [57].



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The thermal efficiency of biomass fuel increases with an increase in calorific value [58]. Therefore, a greater thermal efficiency of 79.9% has been achieved while feeding this SBB in a 5 kW/h downdraft biomass gasifier. Table 5 shows the gasification parameters and thermal efficiency of the SBB. Using the calorific value determined by the bomb calorimeter (18.6 MJ/kg) the power efficiency was calculated as 79.9% (Table 5) which was in good agreement with the recommended range of 70% - 80% [59] while operating in the downdraft mode. The values such as wood consumption rate, gas temperature, charcoal produced, gasifier running time and calorific value of the fuel wood are measured and tabulated (Table 5). The SBB has a higher thermal efficiency of 79.9%. The thermal efficiency of SBB was significantly higher than that of the rice husk briquette (75%) as reported by K. Sivakumar et al., 2012 [60] while fed into a 10kW/h downdraft gasifier. From the above result, the SBB is suitable for the reduction of conventional fuel for power generation.

CONCLUSION

The good mechanical properties such as bulk density, shatter index, durability and water resistance confirm the good quality of the prepared bagasse briquette. Low values of ash content (5.13%), moisture content (10.5%) and high values of Calorific content (18.6 MJ/Kg), volatile matter (74.8) prove that the selected SBB can act as a competitive fuel for other types of briquettes. Higher proportion of Carbon and Hydrogen content promotes higher heating value (18.6MJ/kg). SBB does not release any toxic gases since it contains lower sulphur (0.03%) and nitrogen (0.04%). The maximum mass loss of 53.04% at peak temperature 329.3°C is observed which confirms the better combustion process with an activation energy of 103.12 kJ/mol. From the overall results obtained it is concluded that this study recommends that the briquettes made from sugarcane bagasse with molasses and clay as a binder is the best choice for fuel production and gives a promising alternative for fossil fuels.

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REFERENCES

1. Renewables 2013, Global status report, REN 21, *Renewable energy policy network for the 21st century*.
2. Almeida AN, Angelo H, Gentil LVB, Silva JC GL, Demanda de briquette de madeira, Floresta, Curitiba, PR 2011; 4(1): 73-78.
3. Chinyere D.C., Asoegw S.N., Nwandikom, An Evaluation of Briquettes Binder. *The International Journal of Science and Technology*, 2(7): 147- 157.
4. Yogesh Parab, Siddhesh Nijap, Dr.HarishVankudre, Nikhil Borse, VarrshaSondagar, Apurva Pendbhaje (2020) Producer Gas Generation by Agricultural Waste, *International journal of Engineering Research and Technology*, Vol.9 Issue 07 : 909 -915.
5. Olugbade TO, Mohammed TI (2015) Fuel developed from rice bran briquettes and palm kernel shells, *Int. J. Energy Eng.* 5(2):9–15
6. Israelsen M, Israelsen M, Busk J, Jensen J (1981) Pelleting properties of diary compounds with molasses, alkali-treated straw and other by-products. *Feedstuffs* 7:26-28
7. Wakchaure G.C and Indra Mani (2009), Effect of binders and pressures on physical quality of some biomass briquettes, *Journal of Agricultural Engineering*, Vol. 46(4)
8. Temitope Olugbade, Oluwole Ojo and Tihamiyu Mohammed (2019) Influence of Binders on Combustion properties of Biomass Briquettes: *A recent review*, *BioEnergy Research* 12,241-259.
9. C.Karunanithy, Y.Wang, K.Muthukumarappan and S.Pugalendhi (2012), Physicochemical characterization of briquettes made from different feedstocks, *Biotechnology Research International*, Volume 2012, Article ID 165202, 12.





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10. Suparin Chaiklangmuang, Suwit Supa and Prattana Kaewpet, Development of fuel briquettes from biomass lignite blends, *Chiang Mai J.Sci.* 2008;35(1): 43-50.
11. Kofi Asamoah Adu-Poku, Desmond Appiah, Killian Asampana Asosega, Nana Sarfo Agyemang Derkyi, Felix Uba, Ebenezer Nyarko Kumi, Eric Akowuah, Gilbert Ayine Akolgo, Daniel Gyamfi, Characterization of fuel and mechanical properties of charred agricultural wastes: Experimental and statistical studies, *Energy Reports*, Volume 8 (2022), 4319-4331.
12. Tayade S R. 2009. Evaluation of different biomass briquettes making for gasifier. M.Tech. Thesis (unpub.), Akola. Pp.34-35.
13. Junmeng Cai, Yifeng He, Xi Yu, Scott W. Banks, Yang Yang, Xingguang Zhang, Yang Yu, Ronghou Liu, Anthony V. Bridgwater, Review of physicochemical properties and analytical characterization of lignocellulosic biomass, *Renewable and Sustainable Energy Reviews*, Volume 76:309 – 322.
14. Gifty E. Acquah, Brian K. Via, Oladiran O. Fasina, and Lori G. Eckhardt, Rapid Quantitative Analysis of Forest Biomass using Fourier Transform Infrared Spectroscopy and Partial Least Squares Regression, *Journal of Analytical Methods in Chemistry*, Volume 2016.
15. Jianbiao Liu, Xuya Jiang, Hongzhen Cai, and Feng Gao, Study of Combustion Characteristics and Kinetics of Agriculture Briquette using Thermogravimetric Analysis, *ACS Omega* 2021, 6, 15827 -15833.
16. Lei Tang, Jin Xiao, Qiuyun Mao, Zhenhua Zhang, Zhen YAO, Xiangdong Zhu, Shengchao Ye and Qifan Zhong, Thermogravimetric analysis of the combustion characteristics and combustion kinetics of coals subjected to different chemical demineralization processes, *ACS Omega* 2022, 7, 13998-14008.
17. Alpna Singh, Nishant Kr Srivastava, Vinod Yadav, Davesh Kumar, *Advance Research in Electrical and Electronic Engineering (AREEE)*, Volume 2, Number 5:2015, pp 47-51.
18. P.Kumar, P.M.V.Subbarao, L.D.Kala, V.K.Vijay, Real-time performance assessment of open top downdraft gasifier system, *Cleaner Engineering and Technology* 2022 (100448), Volume 7.
19. Duleeka Gunarathne, Optimization of the performance of down-draft biomass gasifier installed at National Engineering Research and Development (NERD) Centre of Sri Lanka, 2012
20. Umesh Basanagouda Deshannavar, Prasad Gopalkrishna Hegde, Production and characterization of agro-based briquettes and estimation of calorific value by regression analysis: *An energy application, Materials Science for Energy Technologies* 1, (2018), 175-18
21. Zixing Feng, Tao Zhang, Jianfei Yang, Qi Gao, Liangmeng Ni and Zhijia Liu, Fuel characteristics of briquettes manufactured by natural stacking bamboo/Chinese fir mixtures, *ACS Omega* (2020), 5, 39, 25281 – 25288.
22. Joko Waluyo, Muhammad MuadzSetianto, Nadiya RizkiSafitri, Sunu HerwiPranolo, Characterization of biochar briquettes from coconut shell with the effect of binder: molasses, cow manure and horse manure, *Evergreen* 10 (1): 539 – 545.
23. L.Tabil Jr and S. Sokhansanj, Process conditions affecting the physical quality of Alfalfa Pellets, *Applied Engineering in Agriculture*, 12(3): 345-350.
24. J.B.Dobie, W.N. Garrett, J.H. Meyer, G. P. Lofgreen, Effect of pellet size and composition on Feedlot performance, Carcass characteristics and Rumen Parakeratosis of fattening steers, *Journal of Animal Science*, Volume 20, Issue 4, 1962, Pages 833-838.
25. T. Rajaseenivasan, V. Srinivasan, G. Syed Mohamed Qadir, K. Srithar, An investigation on the performance of sawdust briquette blending with neem powder, *Alexandria Engineering Journal*, 2016 (55), 2833 – 2838.
26. Ekhuemelo David Oriabure, Tembe Emmanuel Terzungwue, Obute Faith Emoh, Density, shatter index and heating value of briquettes produced from the leaves of Terminalia Mentalis and sawdust of Daniela Oliveri, *International Journal of Pure Agriculture Advances*, Volume 1 (2017), Issue 1, Pages:38 – 44.
27. S.R.Richards, Physical testing of fuel briquettes, *Fuel Processing Technologies*, Volume 25, Issue 2, 1990, Pp: 89-100.
28. H. M. Faizal, Z. A. Latiff, Mazlan A. Wahid, Darus A. N., Physical and combustion characteristics of biomass residues from Palm Oil Mills, *New aspects of fluid mechanics, heat transfer and environment*, 2010, Pp:34 – 38.
29. McKendry, P. (2002), Energy production from biomass (Part 1), *Overview of Biomass, Bioresource Technology*, 83, 37-46.





Esakkiammal et al.,

30. Anil Kumar Verma, Prasenjit Mondal, Physicochemical characterization and pyrolysis kinetic study of Sugarcane Bagasse using thermogravimetric analysis, *JERT-15-1264*, 2016, 138(5): 052205.
31. D. K. Vyas¹, F.G. Sayyad, M.S. Khardiwar and Shailendra Kumar, Physicochemical properties of briquettes from different feedstock, *Current World Environment*, Vol. 10(1), 263-269 (2015).
32. Mensah L. D.; Buertey K. L.; Kemausor F. (2017) "Experimental Analysis of Three Common Tree Species in Ghana", *International Journal of Engineering Sciences and Research Technology*, 6(6), pp133-141.
33. Andrzej Greinert, Maria Mrowczynska, Radoslaw Grech, Wojciech Szefer, *Energies* (2020), MDPI, Volume 13, Issue 2.
34. N.S.L. Srivastava, S.L. Narnaware, J.P. Makwana, S.N. Singh, S. Vahora, Investigating the energy use of vegetable market waste by briquetting, *Renewable Energy*, Volume 68, 2014, Pp 270-275.
35. Jigisha Parikh, S. A. Channiwal, G.K. Ghosal, A correlation for calculating HHV from proximate analysis of solid fuels, *Fuel* 84 (2005) 487-494.
36. A.Adamovics, R. Platace, I. Gulbe and S. Ivanovs, The content of carbon and hydrogen in grass biomass and its influence on heating value, *Engineering for Rural Development*, Jelgava 2018 Pp:23-25.
37. Anil Kumar Varma and Prasenjit Mondal, Physicochemical characterization on pyrolysis kinetics of wood sawdust, Recovery, Utilization and Environmental Effects, *Energy Sources*, Part A, Volume 38, 2016-Issue 17.
38. Stephen Danje, Fast pyrolysis of Corn Residues for Energy Production, 2011.
39. Akhtar, Nadeem; Goyal, Dinesh; Goyal, Arun, Physico-chemical characteristics of leaf litter biomass to delineate the chemistries involved in biofuel production, *Journal of the Taiwan Institute of Chemical Engineers*, 62, Pp 239-246.
40. Chutiya, Rahul Singh; Katak, Rupam; Bhaskar, Thallada (2013), Thermogravimetric and decomposition kinetic studies of Mesua ferrea L. deoiled cake, *Bioresource Technology*, 139(), 66 – 72.
41. John Coats, Interpretation of Infrared Spectra, A Practical Approach, Encyclopedia of Analytical Chemistry R.A. Meyers (Ed.), John Wiley & Sons Ltd, Chichester, 2000, pp. 10815–10837.
42. Nedret Billor, Gifty E. Acquah, Brian K.Via, Oladrian O. Fasina and Lori G. Eckhardt, Identifying plant part composition of forest logging residue using Infrared Spectral Data and Linear Discriminant Analysis, *MDPI, Sensors* 2016, 16(9),1375.
43. Shadangi, Krushna Prasad; Mohanty, Kaustubha, Kinetic study and thermal analysis of the pyrolysis of non-edible oilseed powders by thermogravimetric and differential scanning calorimetric analysis, *Renewable Energy*, 63(), 337-344.
44. Cheila Gonçalves Mothé, Jaqueline Souza de Freitas, Thermal Behaviour of cashew gum by simultaneous TG/DTG/DSC – FT-IR and EDXRF, *Journal of Thermal Analysis and Calorimetry*, Volume116(2014), Pp 1509-1514.
45. 43.Gordon G. Allison, Simon C. Thain, Phillip Morris, Catherine Morris, Sarah Hawkins, Barbara Hauck, Tim Barraclough, Nicola Yates, Ian Shield, Anthony V. Bridgwater, Iain S. Donnison, Quantification of hydroxycinnamic acids and lignin in perennial forage and energy grasses by Fourier – transform infrared spectroscopy and partial least squares regression, *Bioresource Technology*, Volume 100, Issue 3, (2009), Pp 1252 – 1261.
46. Esin Apaydin-Varol, Ersan Pütün, Ayşe E. Pütün, Slow pyrolysis of pistachio shell, *Fuel*, Volume 86, Issues 12 – 13 (2007), Pp 1892 – 1899.
47. A.O. Balogun, O. A. Lasode, A. McDonald, Thermo – physical, Chemical and Structural Modifications in Torrefied Biomass Residues, *Environmental Science, Materials Science, Chemistry, Waste and Biomass Valorization* (2016).
48. Swapan Suman, Deepak Singh Panwar and Shalini Gautam, Surface morphology properties of biochars obtained from different biomass waste, *Energy Sources, Part A: Recovery, Utilization and Environmental Effects*, Volume 39, 2017 – Issue 10.
49. C. A. Koufopoulos, A. Lucchesi, G. Maschio, Kinetic modelling of the pyrolysis of biomass and biomass components, *The Canadian Journal of Chemical Engineering*, Volume 67, Issue 1(1989), Pp 75 – 84.
50. L.F. Calvo; M. Otero; B.M. Jenkins; A. Morán; A.I. García (2004). Heating process characteristics and kinetics of rice straw in different atmospheres. *Fuel Processing Technology*, 85(4), 279–291.





Esakkiammal et al.,

51. Muhammad Sajjad Ahmad, Hossam A. Gabbar, Exploring bioenergy potential and thermal behavior of Elephant grass cultivated with treated microalgae wastewater for advanced pyrolytic products, *Chemical Engineering Science*, Volume 288 (2024), 119842.
52. Renata M. Braga, Tiago R. Costa, Julio C. O. Freitas, Joana M. F. Barros, Dulce M. A. Melo & Marcus A. F. Melo, Pyrolysis kinetics of elephant grass pretreated biomasses, *Journal of Thermal Analysis and Calorimetry*, Volume 117 (2014), Pp 1341 – 1348.
53. Joanna Wnorowska, Szymon Ciukaj and Sylwester Kalisz, Thermogravimetric analysis of solid biofuels with additives under air atmosphere, *MDPI, Energies* 2021, 14, 2257.
54. Oris Chansa, Zhongyang Luo, Chunjiang Yu, Study of the kinetic behaviour of biomass and coal during oxyfuel co-combustion, *Chinese Journal of Chemical Engineering*, Volume 28, Issue 7 (2020), Pp: 1796 – 1804.
55. Miftahul Hunda, Development of new equations for estimating gross calorific value of Indonesian Coals, *Indonesian Mining Journal*, Volume 17 (2014), Pp: 10 -19.
56. Juan Jesús Rico, Raquel Pérez-Orozco, David Patiño Vilas, Jacobo Porteiro, TG/DSC and kinetic parametrization of the combustion of agricultural and forestry residues, *Biomass and Bioenergy*, Volume 162 (2022), 106485.
57. Gunjan Patil, The possibility study of briquetting agricultural wastes for alternative energy, *Indonesian Journal of Forestry Research*, Volume 6(2) 2019.
58. Qin Cai, Xiaoyang Wu, Yong Huang, Xi Wang, The research on the influence of boiler operating parameters on thermal efficiency, *IOP Conference series Earth and Environmental Science* 585 (1): 012113.
59. Grover, P.D. and Mishra, S.K. (1996) Biomass Briquetting: Technology and Practice. *Regional Wood Energy Development Programme in Asia*. Field Document No. 46, Food and Agricultural Organization
60. K.Sivakumar, N.Krishna Mohan, B. Sivaraman, Performance analysis on Briquetting biomass with different size in 10 kW Downdraft gasifier, *Procedia Engineering*, Volume 38, 2012, Pp 3824 – 3832

Table 1. Physical properties of Sugarcane Bagasse Briquette (SBB)

PARAMETERS	VALUES
Bulk density (kg/m ³)	630
Durability	0.996
Shatter index (%)	99.688
Water resistance (%)	97.272

Table 2. Proximate analysis of Sugarcane Bagasse Briquette (SBB)

PARAMETER	VALUES
Proximate Analysis	
Moisture Content(%)	10.3
Ash Content(%)	5.13
Volatile Matter(%)	74.8
Fixed Carbon(%)	9.57
Calorific Value – Experimental(MJ/Kg)	18.6
Calorific Value – Theoretical (MJ/Kg)	16.57
Difference In Calorific Value	2.03

Table 3. Elemental Composition of Sugarcane Bagasse Briquette (SBB)

ELEMENTS	VALUES
Carbon	62.71
Oxygen	37.1
Silicon	0.14
Chlorine	0.05





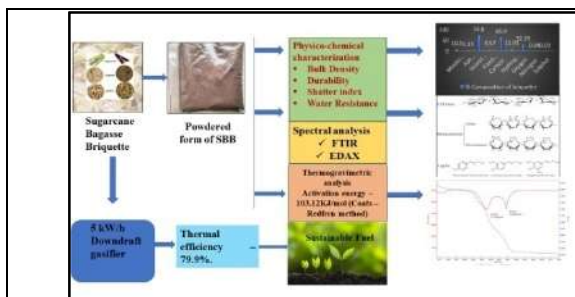
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Table 4. Combustion parameters of SBB

PARAMETERS	VALUES
Ignition temperature T_i (°C)	245.2
Peak temperature T_p (°C)	329.3
Burnout temperature T_b (°C)	468
Maximum decomposition rate (%/min)	3.331
Average burning rate (%/min)	7.583
Combustion characteristic index, S_N (10^{-7})	8.9

Table 5. Gasification Parameters and thermal efficiency of Sugarcane Bagasse Briquette

CHARACTERISTICS	SUGARCANE BAGASSE BRIQUETTE
Wood consumption rate (kg/hr)	20
Gas temperature (°C)	46
Charcoal produced (kg)	3.100
Gasifier running time (Hrs)	2
Calorific value (MJ/Kg)	18.6
Efficiency (%)	79.9
Gas/Fuel ratio(kg/m ³)	2.91



GRAPHICAL ABSTRACT

Fig. 1 Sugarcane Bagasse Briquette (SBB)

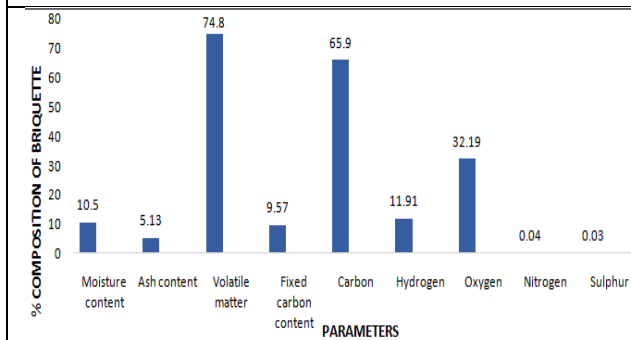


Fig. 2 Percentage composition of SBB (proximate and ultimate analysis)

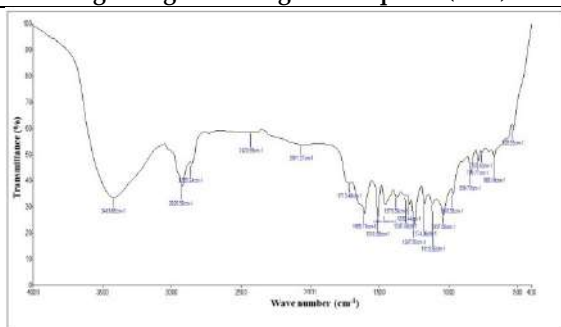


Fig. 3 FT-IR Spectra of Sugarcane Bagasse Briquette (SBB)





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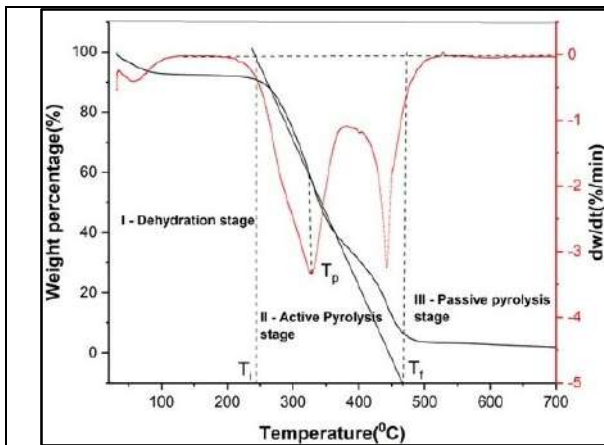


Fig 4. TG and DTG curves of Sugarcane Bagasse Briquette

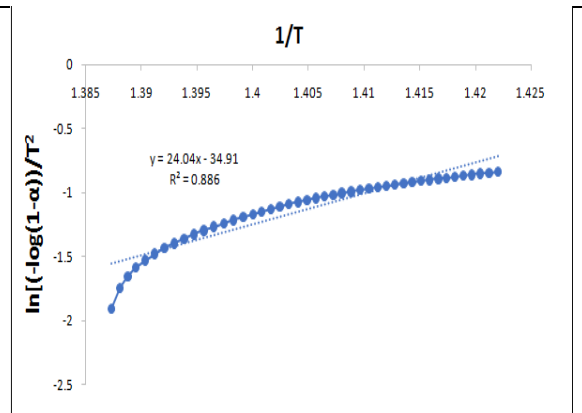


Fig 5. Activation energy calculation by Coats -Redfern method





Securing the Future: A Comprehensive Review of Block Chain Security Protocols and Challenges

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ABSTRACT

Blockchain, as a decentralized technology, possesses considerable potential for addressing various business challenges. The security of records in block chain transactions is ensured through cryptographic measures, and each transaction is intricately linked to preceding records. The validation of blockchain transactions relies on algorithms embedded in the network nodes, preventing any single entity from independently creating transactions. Notably, block chains offer transparency, empowering every participant to observe transactions in real-time. The implementation of smart contracts enhances transaction security, eliminating the need for third-party intervention. Ethereum, serving as a decentralized platform for smart contracts, facilitates the creation of markets and the seamless movement of funds based on predefined instructions. Key attributes of block chain encompass decentralization, immutability, expeditious transactions, and swift validation processes.

Keywords: The implementation of smart contracts enhance transaction security, eliminating the need for third-party intervention.

INTRODUCTION

Blockchain technology holds immense potential across diverse applications and presents extensive opportunities for various infrastructures. It fosters efficient resource management and ensures secure communication. The utilization of block chain in financial transactions enhances trust by reducing the likelihood of fraud and automatically generating a comprehensive activity record. The system also facilitates automated background checks for any participant within the network. Decentralization inherent in block chain technology establishes reliability and minimizes risks associated with entering business agreements with unfamiliar parties. In today's technologically advanced era, people extensively use the internet for communication through various means such as voice calls, video calls, messages, and sharing



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pictures. Traditionally, these transactions required a trusted third party to facilitate the process. However, block chain introduces a paradigm shift by providing robust security in transactions, eliminating the need for a central authority. In the context of financial transactions, where trust is crucial, block chain ensures a secure environment. Each transaction is recorded in a block, functioning as a permanent database and serving as a transparent record book. Once a transaction is completed, the block becomes part of the blockchain. The addition of a new block occurs either upon completion of a transaction or through the generation of a new block. Each block carries a hash of the previous block, ensuring the integrity and security of the entire transaction history.

KEY ATTRIBUTES OF BLOCKCHAIN TECHNOLOGY**Decentralization**

Decentralization stands in stark contrast to centralization, offering enhanced security and flexibility compared to centralized applications. The need for swift decision-making has prompted numerous organizations to embrace decentralization. In a centralized setup, all activities are concentrated in a single location, whereas decentralization involves operations across different locations. This approach has the capability to deliver both efficiency and innovation. Efficiency, in the context of decentralization, involves the saving of costs and time, ultimately yielding improved results. The distributed nature of decentralized systems contributes to streamlined processes and resource utilization. On the other hand, innovation in a decentralized environment introduces new ideas, leading to novel benefits and solutions. By fostering a diverse and collaborative ecosystem, decentralization promotes adaptability and creativity, making it a preferred choice for organizations seeking to balance efficiency and innovation in their operations.

Trust

In Blockchain technology, each block contains information referencing the previous block, establishing an authentication mechanism for transactions. Unlike traditional setups, there is no need for third-party communication; instead, a public ledger is utilized. Every transaction is automatically recorded in this ledger, ensuring transparency and traceability throughout the block chain network. This decentralized and self-sufficient system eliminates the reliance on intermediaries, enhancing the security and efficiency of transactions.

Transparent

Blockchain technology ensures that stored data is both transparent and immutable, contributing to the inherent trustworthiness of block chains. Transparency is maintained as the data in a block chain is accessible to all participants in the network, providing a clear and open view of transactions. This transparency builds trust among users as they can independently verify and validate information. Immutability, on the other hand, refers to the resistance of data to alteration or tampering once it has been added to the block chain. Each block contains a cryptographic hash of the previous block, creating a chain that links all the blocks together. Any attempt to modify the information in a block would require altering all subsequent blocks, which is computationally infeasible. This immutability ensures the integrity of the data and reinforces the reliability and trustworthiness of the information stored in the block chain.

PUBLIC AND PRIVATE BLOCKCHAIN

Blockchain is primarily categorized into three types: Public, Private, and Consortium block chain. This paper aims to explore and compare the recent properties of public and private block chains, emphasizing both their similarities and differences in functionality. Public and private block chains share certain characteristics, such as the fundamental principles of distributed ledger technology and the use of cryptographic techniques to secure transactions. However, their distinctions lie in their accessibility, control, and the level of decentralization. Public block chains, like the well-known Bit coin and Ethereum networks, are open to anyone and allow for permission less participation. They operate in a decentralized manner, with a network of nodes collectively validating and confirming transactions. Public block chains often prioritize transparency and censorship resistance. In contrast, private block chains restrict access to a specific group of participants. These networks are typically permissioned, meaning participants must be authorized to join. Private block chains are characterized by a higher level of control, making them suitable for applications



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within closed ecosystems or organizations where privacy and restricted access are paramount. This paper will delve into a comprehensive comparison of these block chain types, exploring their functionality in terms of security, scalability, consensus mechanisms, and the implications of their design choices on various use cases. By evaluating these recent properties, a deeper understanding of the strengths and limitations of public and private blockchains can be gained, aiding in informed decision-making for the implementation of blockchain solutions in diverse scenarios.

Challenges in Blockchain Technology

Blockchain technology, particularly in the context of Bitcoin transactions, faces several challenges that impact its functionality. Here are some typical challenges and potential solutions:

Scalability**Challenge**

The increasing number of transactions poses scalability issues. Large block sizes can lead to delays as miners prioritize high transaction fees.

Potential Solutions

Storage Optimization: Enhance the efficiency of block chain storage.

Redesigning Blockchain: Explore new architectural approaches to improve scalability.

Privacy Leakage**Challenge**

While users believe block chain offers enhanced privacy, studies reveal that transactions can be linked to user identities, compromising privacy.

Potential Solutions

Elliptic Curve Diffie-Hellman-Merkle (ECDHM): Implement ECDHM for secure key exchange.

Secured Platforms: Utilize secured platforms like smart contracts and Ethereum for confidential transactions.

MITM Attack (Man in The Middle Attack)**Challenge**

MITM attacks involve a third party intercepting data using a forged public key, compromising the security of blockchain transactions.

Potential Solutions

Immutable Public Key: Due to the immutability of public keys in blockchain, the risk of attack by forged keys is reduced.

Secure Linking of Blocks: Ensure each block is securely linked to previous and following blocks.

DDoS Attack (Distributed Denial of Service)**Challenge**

DDoS attacks can significantly disrupt blockchain operations, creating business risks.

Potential Solutions

Enhanced Security Measures: Implement robust security measures to mitigate DDoS risks.

Network Resilience: Develop strategies to enhance the resilience of the blockchain network against DDoS attacks.

Addressing these challenges requires a combination of technological innovations, security measures, and a continuous commitment to improving the efficiency and security of blockchain systems.

Using a Flow Analytics Device to Mitigate DDoS Attacks

A Flow Analytics Device is a common solution employed to counter Distributed Denial of Service (DDoS) attacks. This device serves as a vigilant guardian that monitors network traffic and responds dynamically to mitigate the impact of potential attacks. Here's how it typically works





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Traffic Monitoring

The Flow Analytics Device continuously analyzes incoming network traffic, scrutinizing patterns, and identifying anomalies.

Anomaly Detection

By comparing the observed traffic against predefined baselines and patterns, the device can identify deviations that may indicate a DDoS attack.

Attack Recognition

Once anomalous patterns indicative of a DDoS attack are recognized, the Flow Analytics Device classifies the malicious traffic, distinguishing it from legitimate requests.

Decision Making

Based on the analysis, the device makes real-time decisions on how to handle the identified malicious traffic. It determines the appropriate course of action to mitigate the impact of the attack.

Traffic Redirection

A key feature of the Flow Analytics Device is its ability to redirect or filter out malicious traffic. By steering the unwanted traffic away from the target system, the device helps ensure that legitimate requests are processed efficiently.

Communication with Network Elements

The device communicates with other network elements, such as routers or firewalls, to implement the recommended actions. This may include updating access control lists (ACLs) or adjusting routing configurations.

Traffic Clearing

Through proactive measures, the Flow Analytics Device contributes to clearing the network of malicious traffic, allowing normal operations to resume.

Continuous Monitoring and Adaptation

The device continually monitors the network, adapting its responses to the evolving nature of DDoS attacks. This adaptive capability enhances its effectiveness in countering new and sophisticated attack patterns. Implementing a Flow Analytics Device as part of a comprehensive cybersecurity strategy can significantly enhance a system's resilience against DDoS attacks. Its ability to swiftly identify, classify, and mitigate malicious traffic helps maintain the availability and reliability of network services.

SECURITY FEATURES OF BLOCKCHAIN

Utilizing Ledger and Security Features in Blockchain Technology

Blockchain technology incorporates a ledger system and security features to ensure the integrity and confidentiality of transactions. Here's an overview of how these components contribute to the robustness of blockchain:

Immutable Ledger

In blockchain, a ledger records each transaction, and it is immutable. This means that once a transaction is recorded in a block, it cannot be edited or deleted. This immutability ensures the integrity of the transaction history, providing a secure and tamper-resistant record.





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Decentralization and Limited Access

The ledger in blockchain is part of a decentralized application. This decentralization means that no single entity has control over the entire ledger. Each participant in the network has a copy of the distributed ledger, and consensus mechanisms are employed to authenticate transactions. Only read access is granted to users, ensuring that sensitive data remains secure. Decentralization enhances security by preventing unauthorized access and reducing the risk of a single point of failure.

Chain of Blocks and Hashing

Each block in the blockchain contains a hash value, and these blocks are linked together by referencing the hash of the previous block. This creates a chain of blocks, and any attempt to alter data in a block would require changing its hash, affecting all subsequent blocks. The chain of blocks, coupled with cryptographic hashing, enhances the security of sensitive data. Even a minor alteration to any block would disrupt the entire chain, making it computationally infeasible for an attacker to tamper with the data.

Peer-to-Peer Communication

Blockchain operates as a decentralized application, supporting peer-to-peer communication. Nodes in the network, which are essentially computers, authenticate and validate transactions. Thousands of nodes in the network maintain copies of the distributed ledger. Consensus mechanisms, such as Proof of Work or Proof of Stake, ensure that all nodes agree on the validity of a transaction before it is added to the blockchain. If any node dissents, the transaction is rejected, protecting the network from fraudulent activities.

APPLICATIONS OF BLOCKCHAIN TECHNOLOGY

Blockchain technology offers transformative solutions in the healthcare industry, addressing privacy concerns, enhancing electronic medical records (EMRs), protecting personal data, and revolutionizing digital currencies like Bitcoin. Here's a breakdown of its applications:

Patient Privacy and Secure Transactions

- Scenario: Patients prefer keeping their treatment details secure.
- Blockchain Solution:
- Utilizes public and private keys for secure transactions.
- Example: Alice digitally signs data with her private key, hashes it with her public key, and Bob validates the digital signature before the transaction proceeds.

Electronic Medical Records (EMRs)

- Scenario: Patients want control over their medical data, addressing privacy concerns with existing EMRs.
- Blockchain Solution:
- Implements decentralized applications (dApps) for managing electronic medical records.
- Addresses challenges by securely exchanging data between parties, ensuring confidentiality, and maintaining accountability.

Protecting Personal Data

- Scenario: Increasing incidents of security problems in users' personal data.
- Blockchain Solution:
- Eliminates third-party control over personal data.
- Empowers users as owners of their data through smart contracts, ensuring secure peer-to-peer communication.

Bitcoin and Decentralized Transactions

- Scenario: Introduction and increasing popularity of Bitcoin for online transactions.
- Blockchain Solution:



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- Bitcoin operates as a decentralized application on the blockchain.
- Ensures transparency and security in digital currency transactions.
- Utilizes smart contracts to establish rules and regulations for peer-to-peer transactions.

Key Insights

- Blockchain's decentralized nature addresses trust and security concerns by eliminating reliance on third parties.
- Smart contracts play a pivotal role in establishing rules and regulations before transactions, enhancing security and accountability.
- The immutability of blockchain ensures data integrity, making it a robust solution for managing sensitive information.

Challenges and Considerations

- Implementing blockchain in healthcare may face challenges, such as the integration of existing systems and adherence to regulatory requirements.
- Smart contract development and standardization are crucial for interoperability and seamless adoption across healthcare systems.

Smart Contracts

Smart contracts, also known as crypto contracts, were initially proposed by Nick Szabo in 1994. These are computer programs that directly control the transfer of digital currency. They are stored on blockchain technology, operating as decentralized systems involving two parties. Smart contracts eliminate the need for intermediaries, saving time and reducing conflicts. These contracts leverage ledgers, serving as decentralized applications within the blockchain network.

Ledger

A ledger is a decentralized application assigned to each user in a blockchain. After a transaction is completed, it is automatically recorded in the ledger. For instance, if person A owes 100 rupees to person B, this transaction is reflected in the ledgers of all participants. In a scenario where person A claims to only owe 10 rupees to person B, a voting mechanism is employed. This mechanism validates or rejects statements based on the consensus of the network, ensuring accuracy and transparency. Public ledgers are particularly well-suited for cryptocurrency transactions, providing decentralized and tamper-resistant data storage without a central administrator.

Ethereum

Ethereum is a decentralized platform designed to run blockchain applications, allowing developers to build and deploy decentralized applications (DApps). While Ethereum shares similarities with Bitcoin as a distributed public blockchain network, there are technical differences. Ethereum requires maintaining the current state information for each application, including user balances and smart contract code. Ether, the native cryptocurrency of the Ethereum platform, facilitates transactions and interactions within the Ethereum network. Ethereum's flexibility and support for smart contracts make it a powerful tool for decentralized application development.

OTHER APPLICATIONS

Blockchain technology has found diverse applications across various industries, with finance being a prominent sector. Here are some key applications:

Secure Transactions in Banking

Blockchain is adopted by banking professionals to enhance the security of transactions. It provides a decentralized and tamper-resistant ledger, reducing the risk of fraud and ensuring the integrity of financial transactions.





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Cryptocurrencies

Cryptocurrencies, such as Bitcoin and Ethereum, operate on blockchain technology. Blockchain ensures secure and transparent peer-to-peer transactions, offering an alternative to traditional financial systems.

Smart Contracts in Finance

The finance industry leverages smart contracts to automate and enforce contract terms. These self-executing contracts eliminate the need for intermediaries, streamlining processes, reducing costs, and minimizing the risk of disputes.

Supply Chain Management

Blockchain enhances transparency and traceability in supply chain management. It allows stakeholders to track the flow of goods, verify authenticity, and ensure the integrity of product information.

Cross-Border Payments

Blockchain facilitates faster and more cost-effective cross-border payments by eliminating intermediaries and reducing transaction times. This is particularly beneficial for international transactions in the finance industry.

Tokenization of Assets

Assets, such as real estate or art, can be tokenized on blockchain platforms. This process divides the ownership of assets into digital tokens, providing fractional ownership opportunities and increasing liquidity in financial markets.

Decentralized Finance (DeFi)

DeFi platforms leverage blockchain to offer decentralized financial services, including lending, borrowing, and trading, without traditional intermediaries. This enhances financial inclusion and provides alternative financial solutions.

Digital Identity Verification

Blockchain ensures secure and verifiable digital identity solutions. It allows individuals to control and share their personal information securely, reducing the risk of identity theft.

Insurance and Risk Management

Blockchain streamlines insurance processes, from underwriting to claims processing. It enhances transparency and trust in the insurance industry by providing a secure and auditable record of transactions.

Healthcare Data Management

Blockchain is utilized to secure and manage healthcare data, ensuring privacy and interoperability. It enables patients to have more control over their medical records and facilitates secure sharing of information among healthcare providers.

Analysis on Blockchain Security

Identification of Security Issues

The paper effectively highlights that blockchain technology faces security challenges that can impact transactions. It acknowledges the existence of various types of attacks and emphasizes the need for solutions to mitigate these issues.

Focus on Public and Private Blockchains

The paper concentrates on both public and private blockchain networks, providing a comparative analysis. This approach allows readers to understand the differences in security considerations between these two types of networks.





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Types of Blockchain Networks

The identification of three main types of blockchain networks (public, private, and consortium) shows a comprehensive understanding of the blockchain landscape. However, the review paper specifically focuses on public and private blockchains.

Comparison Table

The inclusion of a comparison table between public and private blockchains adds clarity to the review. It succinctly summarizes the key differences, such as read permissions, immutability, efficiency, and centralization, aiding readers in understanding the distinctions between these two blockchain types.

Recognition of Blockchain's Trending Significance

The acknowledgment that blockchain technology is a trending and influential technology indicates an awareness of its widespread adoption. The paper recognizes the growing number of applications developed based on blockchain, emphasizing its relevance in various industries.

Proposal of Solutions

The paper contributes to the field by proposing solutions to recent issues in blockchain technology. By addressing security concerns and suggesting potential solutions, the review paper provides valuable insights for researchers, developers, and practitioners in the blockchain space.

Scope Limitation

The review paper, while informative, acknowledges its focus on specific types of blockchain networks and does not cover consortium blockchains. Expanding the scope to include consortium blockchains could provide a more holistic view of blockchain security considerations.

Overall Contribution

The review paper contributes to the understanding of blockchain security by providing an analysis of challenges and solutions. It serves as a valuable resource for individuals seeking insights into the security aspects of blockchain technology.

CONCLUSION

In conclusion, blockchain technology stands out as a revolutionary force in recent years, offering unprecedented security and efficiency across various applications. Initially designed to handle Bitcoin transactions, blockchain has evolved to become a versatile tool with applications such as smart contracts, the Ethereum platform, and distributed ledgers. The decentralized and tamper-resistant nature of blockchain ensures enhanced security during transactions, making it an ideal choice for handling sensitive data. Its cryptographic principles contribute to a secure and transparent environment, reducing the risk of unauthorized access and data breaches. The widespread use of blockchain, particularly in Bitcoin transactions, has demonstrated its ability to provide faster and more cost-effective solutions compared to traditional applications. Blockchain's decentralized and automated features contribute to the efficiency and reliability of transactions, making it a preferred choice in the digital landscape. Moreover, blockchain applications benefit from the technology's inherent transparency and immutability. Transactions recorded on the blockchain are visible to all participants, fostering trust and ensuring the integrity of data. As blockchain continues to advance and find new applications, it is clear that the technology has the potential to reshape industries, offering innovative solutions to longstanding challenges. Its transformative impact on security, transparency, and efficiency positions blockchain as a key player in the future of digital transactions and decentralized systems.





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REFERENCES

1. Blockchain for Innovation. "Blockchain Technology: Security and Beyond." Available at: http://www.blockchain4innovation.it/wp-content/uploads/sites/4/2017/05/Blockchain
2. CoinDesk. "Who Created Ethereum?" Available at: https://www.coindesk.com/information/who-created-ethereum
3. CoinDesk. "How Ethereum Works." Available at: https://www.coindesk.com/information/how-ethereum-works
4. Lin, Iuon-Chang, and Tzu-Chun Liao. "A Survey of Blockchain Security Issues and Challenges." January 12, 2017.
5. Mandl, Kenneth D., Peter Szolovits, and Issac S. Kohane. "Public Standards and Patients Control: How to Keep Electronic Medical Records Accessible but Private." February 3, 2001.
6. Blockgeeks. "Smart Contracts." Available at: https://blockgeeks.com/guides/smart-contracts/
7. Azaria, A., Ekblaw, A., Vieira, T., & Lippman, A. "Medrec: Using Blockchain for Medical Data Access and Permission Management." In 2016 2nd International Conference on Open and Big Data (OBD), August 2016, pp. 25-30.
8. Zyskind, G., Nathan, O., & Pentland, A. "Decentralizing Privacy: Using Blockchain to Protect Personal Data." In Security and Privacy Workshops (SPW), 2015 IEEE, May 2015.
9. "Blockchain Challenges and Opportunities: A Survey." Available at: https://www.researchgate.net/publication/319058582
10. Ministry of Economy, Trade, and Industry (METI), Japan. "Study Group Report on the Utilization of Blockchain Technology." Available at: http://www.meti.go.jp/english/press/2016/pdf/0531_01f.pdf
11. Dotmagazine. "Security and Privacy in Blockchain Environments." Available at: https://www.dotmagazine.online/issues/innovation-in-digital-commerce/what-can-blockchain-do/security-and-privacy-in-blockchain-environments
12. Business2Community. "Issues in Blockchain Security." Available at: https://www.business2community.com/tech-gadgets/issues-blockchain-security-02003488

Comparison Table 1: Public Blockchain vs. Private Blockchain

Property	Public Blockchain	Private Blockchain
Read Permission	Public - Open to anyone	Could be public or restricted access
Immutability	Approximately beyond tampering	Could be tampered with, depending on permissions
Efficiency	Low	High
Centralization	Decentralized - No central authority	Centralized or partially centralized (dependson design)





Can Humanism Lead to Happiness?: Examining Mamet's Humanistic Outlook in 'Reunion'

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ABSTRACT

This study delves into the humanistic outlook of David Mamet, an American playwright, specifically in his play 'Reunion'. It aims to examine and explore Mamet's portrayal of human values and experiences in 'Reunion' and appraise his belief that humanism can lead to individual and collective happiness. The study highlights the under-explored aspect of Mamet's work: his humanistic vision. While he is recognized for his moral themes, language mastery, social commentary, and realism, this study offers a fresh perspective by focusing on his portrayal of the human existence. By analyzing 'Reunion' through a humanistic lens, the study promises to make a significant contribution to Mamet's scholarship, offering a deeper understanding of his work and its underlying humanistic vision.

Keywords: humanism, humanistic outlook, materialism, reunion, companionship.

INTRODUCTION

In the process of evolution, human beings have gone through several stages of civilization. In their attempts to find out the means of a successful and significant life, they have framed and sought solace in many philosophical vocations. Of all the concepts that are in vogue, the only term that is closest to 'human' is humanism. In this world that revolves around materialism, the term humanism has humans as its central concern.





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The humanity's unparalleled capacity to reason out or rationalise their actions, their ability to solve problems and sort out issues, and above all, their immeasurable faculty for creativity are the basis of humanism, 'the human-centered theory of life' (Lamont 1997). This philosophy ensures humanity's happiness in this worldly life by advocating a congenial environment for promoting relationships among themselves and with nature. In addition, it understands the need for individual's interest and growth. Further, it advocates a shift from self-regard to concern for globe. Rejecting belief in God and other supernatural elements, humanism states that human beings are responsible for their own actions. It also insists on humans' responsibility to create their own 'ethical universes' (Kurtz 1988). Humanism is not about just existence, it is about living; it is not about simply seeking life, it is about good life with significant experience, happiness and satisfaction. It has the capacity to motivate humankind with the thought that life is worth living and to minimize the existential dilemma during moments of despair in people's lives. As James R. Flynn (1973) states, "Men do not achieve happiness by brooding about happiness but by living." This concept teaches human beings to recognize the universe for what it is, to live without doubt of other worldliness or life after death, to discover the joy of living and to attain fullness of life.

In their struggle for survival, humans have forgotten to live their lives happily and meaningfully in the modern world. With the advancements of technology, they seem to lose control over their actions and an irresponsible attitude creeps in as they put the blame on an unseen God for all their mistakes and failures. Since humanism advocates humans' existence for themselves and upholds them as a measure of all things, a study of humanism is found relevant and essential.

AIM AND SCOPE OF THE STUDY

The aim of this study is to examine and explore humanism in Mamet's 'Reunion'. It also proposes to appraise his faith that humanism will bring happiness not only to the individual, but also to the entire humanity. David Mamet, a modern American playwright, has a good concern for humanity and his plays are found rich in humanism. Hence, a study to ascertain his humanistic vision is appropriate. Also, Mamet has so far been acknowledged only as a moral playwright, a language craftsman, a social dramatist and a realist. So, a study of his humanistic vision will certainly be a substantial contribution to David Mamet's scholarship.

LITERATURE SURVEY

Mamet's Remarkable Journey as a Writer

David Alan Mamet, a prolific playwright of the 20th century, was born on the 30th November in 1947 in Chicago. His mother, Leonore, was a teacher, and father, Bernard, a labour lawyer. After his parents divorced, Mamet lived with his mother and studied in a private school in the Chicago suburb of Olympia fields. It was during this time that he worked for the Hull House Theater and Chicago's improvisational theater. This group which patronised young talents had great influence on his works. He also had an opportunity to appear on television and played the roles of Jewish children with religious issues. His first play was a revue called 'Camel' written in 1968, when he was in Goddard College in Plainfield, Vermont.

Apart from making him a 'language playwright,' (Kroll 1977) the city of Chicago and his experiences have provided him with the subject for his plays which are as Bigsby states, "about spiritually dispossessed, about people who are the alienated products of capitalism, and of their substitution of fantasy for will, sensation for relationship" (Bigsby 1985). For a short while, he worked as a drama teacher at Marlboro College, Vermont. Later, he returned to Goddard College, where he started writing plays to be taught in acting classes. It was partly because of this, he established the St. Nicholas Company which performed both Mamet's plays and works by other playwrights. More than forty plays, twenty screenplays, and nearly ten collections of essays that Mamet wrote earned him a national reputation as a writer with distinctive talent. Mamet's writings have brought him unparalleled recognition and reputation as a social critique, realist and a moralist. Literature survey of Mamet criticism reveals that his humanistic vision has rarely been explored in a full-length study.





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Best known for his plays and screenplays, Mamet established himself as a worthy successor to renowned American playwrights like Eugene O' Neill, Arthur Miller and Tennessee Williams. When he made his entry into the American theater in the 1970s, the Off and Off-Off Broadway were facing an unprecedented decline. While the major celebrities of the American theater like Miller and Albee, who had made substantial contribution to the theater, were disappearing, he brought to the American theater innovation in the form of distinctive language usage (Bigsby 1985).

Mamet believes that theater is the unity of actor and audience in pursuit of truth. He compares the design of a play with the design of a plane. In his 'True and False: Heresy and Common Sense for the Actor,' Mamet (1999) states that an actor need not strive to create an emotional state in oneself while performing on the stage. He holds that a play should be arranged sequentially in a series of incidents through which the protagonist fights against the odds and moves toward the goal and the actor's job is to just utter the lines using his or her will and common sense, aimed at achieving the goal similar to that of the protagonist. According to him, "Great drama, onstage or off, is not the performance of deeds with great emotion, but the performance of great deeds with no emotion whatever" (Mamet 1999). He calls 'this simple performance of the great deed 'heroism.'" A person with such heroic qualities is the one who can inspire the onlookers. Such performances will bring in the unity between the actor and the audience. He emphasizes that this can be attained only through the power of the script. Mamet's dramatic theory not only distinguishes him as a writer with a unique talent for language, but also as a dramatist attempting to understand human beings and the world (Mamet 1999).

The Principles of Humanisms

According to the seventh edition of the 'New Oxford Advanced Learner's Dictionary' humanism is "a system of thought that considers that solving human problems with the help of reason is more important than religious beliefs. It emphasizes the fact that the basic nature of human is good" (Hornby 2005). Corliss Lamont, the author of 'Humanism as a Philosophy,' which is considered the Bible of Humanism, states that "Humanism, in brief is a philosophy (religion) the guiding principle of which is concentration on the welfare, progress and happiness of all humanity in this one and only life" (Lamont 1997). This 'human-centered theory of life' (Lamont 1997) insists on enjoying all the material and cultural prosperity by both the individual and the society. It ultimately means that this world, the nest of human beings, will and shall provide the human beings with a prosperous life and that searching for happiness elsewhere is not only meaningless, but also useless, because "Humanism simply means "human being-ism, that is, devotion to the interests of human beings, wherever they live and whatever their status" (Lamont 1997). This ensures a comfortable and unpretentious life for humans on this earth.

To lead a happy and contented life, humans should have interest in their own selves basically. Great people like Jesus, Buddha, Mother Teresa and Mahatma Gandhi paid attention to their individual interest, which, with the maturity of their thoughts and actions, gradually developed into global interest. Their self-regard was to achieve their goals of serving humanity and bringing in enlightenment and happiness in the lives of human beings. Though they served others, the goals were theirs. It was the self-satisfaction they had in their services that gave them the status of 'humanitarians of all ages'. Self-satisfaction, for each of them, came in different forms: giving his life for human beings to Jesus, serving the country and community to Mother Teresa and the Mahatma, and attaining 'Nirvana' to the Buddha. Though they did not aim at achieving global identity, it came as a result of their services to humanity. Hence, self-regard or interest in one's own self is the foundation for the happiness of human beings.

In the humanist's perspective, one's interest can be interpreted as taking care of or fulfilling one's own needs and interests. Burckhardt considers this self-awareness or self-consciousness as a distinctive mark of Italian Renaissance (Bullock 1985). While regard for the self-motivates a person to lead a meaningful life, lack of it results in existential dilemma. Everything may appear meaningless and lead to psychological disorder or self-destruction. The role of individual's welfare in such contexts is note-worthy. In their aspiration to fulfill their wishes and desires, humans try to overcome the frustrations and failures, because life appears to be worth-living for a self-motivated person. Furthermore, they do not want to make an ordinary living, which is just an existence. They strive to achieve 'fullness of life' (Kurtz 1974) and to live fully well. They find satisfaction and sense of achievement, depending upon their



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individual nature. Generally, “Self-regard in the sense of keeping healthy, acquiring an education, earning a living and finding a congenial life partner is something to be encouraged” (Lamont 1997). In this pursuit of healthy and useful life, humans can find happiness and feel the goodness of being. But, to become complete human beings, they should also look beyond themselves. Those who look only within themselves and take care of only their needs and interests, will, after sometime, suffer from alienation, because, in such cases, self-regard develops into selfishness which will not allow them to promote healthy relationships with others. Hence, at least in their own interest, humans should look outside. Thus comes their responsibility or duty to their family, city, country and the world at large.

As Kurtz says, “A reflective person who is morally concerned must be at some point extend his range of interest to the wider community of man. One cannot help but recognize the claims that all men now have on every man” (Kurtz 1974). A person, apart from enjoying health, economical soundness, familial prosperity should be useful socially, too.

To a question, “Why ought I to be concerned with harmonious transactions?” Kurtz (1988) responds thus,

The answer here is twofold. First, because it is in each person’s self-interest, for virtually everything that a person wants in life involves other human beings Second, ethics does not and cannot rest solely on egoistic consideration ... There is a deeper aspect to the ethical life, however: moral awareness is rooted within our nature as human beings. There is a built-in dependency relationship based on socio-biological roots and cultural conditioning, and this reflects itself in our emotions. We generally or potentially have compassionate regard for others. Thus, social-interest, and not merely self-interest can motivate us.

Being social animals, humans have moral obligation to the society, which in one way, or the other, satisfies their needs. Since they take whatever and whenever they want from the society, they should remain obliged to pay back their debt to the society. This logic, which sounds very simple, requires a lot of commitment and discipline on the part of the human beings to execute. The important needs of humans are food, clothing and shelter. Apart from these three basic things, they need human companions. Without relationship or companionship, life will be colorless and uninteresting. Hence, humans should take care to establish and maintain the relationship. Due to the advancements in Communication Technology, they are able to communicate with each other and form relationship easily. But, there seems to be some difficulty in maintaining it. Two major reasons are their egoistic attitude and misconception about others, especially, the opposite gender. To establish and maintain good relationship with everyone, humans should learn to compromise and get rid of prejudices.

Sufferings in life weaken human beings. These will shatter humans’ hopes of fulfilling the needs of their lives. To overcome this hurdle, humanity should remember that the sufferings are short lived and fight against them. Understanding the transient nature of hardships will help humans improve their confidence level and work for fulfilling their needs. Humanism, being a simple philosophy, becomes a working principle even for average thinking men and women, who aspire to lead happy and useful lives. This being a philosophy of service for the immense good of all humanity in this world through methods of reason, science and democracy, has scope for development of various aspects of human nature. To analyze what is genuine and good, humanism seeks the faculty of reasoning. In addition, it considers the emotional aspects of human feelings, because one of the main concepts of humanism is relieving the emotional burdens of man.

If ‘Humanism’ is considered by many as just a philosophy that is consciously opposed to the belief in God and supernatural elements in the West, it has good scope for preserving and promoting the moral and spiritual traditions declining supernatural factors in the Indian context. In India, humanism has tremendous applications. This is evident in many philosophies expounded in India – the Advaita Vedanta, which promotes Atma as the first and foremost principle of the universe, the concept of Jivanmukti, liberation-in-life on earth and the renowned epic ‘The Mahabharatha’ which asserts man as the superior being. In India, because of the presence of diverse communities and cultures, the need for humanism is more to bring in a harmonious blend of diversities thereby ensuring moral,



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intellectual, and material progress of the country. The father of the Nation, Mahatma Gandhi and the first Prime Minister of Independent India, Jawaharlal Nehru, to name a few, were great humanists (Devaraja 1988). Works of renowned Indian writers like Tagore and GirishKarnad reflect their humanistic outlook. In his drama 'Chandalika,' Tagore (1990) brings out the self-awareness in a girl and cleanses her self-degradation to make her understand the worthiness of her own being. This play is one of the best humanistic works. GirishKarnad's humanistic approach to life can be understood when one of his characters Hayavadana expresses his disbelief in the sins committed in the previous birth: "It has got nothing to do with my last birth. It is this birth which I can't shake off" (Karnad 2000). He also shows staunch belief in the inevitable present.

The famous Tamil poet SubramaniaBharathi's works too project his humanistic inclinations. In his work 'Essays and other Prose Fragments,' he states that an individual, who wants to lead a good social life, should observe good principles and values in personal life first (Bharathi 1937). Thus, through their works, writers of all ages have explored and highlighted the different dimensions of humanism. This concept, which has evolved over the years, has become the guiding principle of humans' lives on this earth. Corliss Lamont (1997) quotes an English Bishop who says that fifty percent of the intelligent people of the modern world are humanists. As Ehrenfeld says, "Most people like to call themselves humanists because the name has acquired pleasant connotations, like 'freedom'" (Ehrenfeld 1978). People today are interested in their present and future life on this earth. Though they do not recognize clearly the direction in which they are moving, their highest aims about their everyday existence embody the viewpoint of humanism.

Thus, humanism, as a philosophy, with constant and relevant changes in the phraseology, will hold good for human beings of all generations, the past, present and future. As a human-centered theory, this should be able to improve and enhance all the contemporary and relevant socio-economic programs like capitalism, free enterprise, collectivism, socialism and communism to a considerable degree. As Lamont (1997) says, "all these economic and political systems may come and go; nations, empires and civilizations may rise and fall, but Humanism, as a philosophic system in which humankind's interests upon this earth are the first word and the last word, is unlikely to become obsolete." Since the philosophy is propounded by humans and for humans, this is taken care of by humanity across the globe.

MAMET AND HUMANISM

David Mamet gives eloquent voice to the ever new joy of living and to the worthiness of existence, through his plays. For him, the ideal human being is universal with many dimensions delighting in every kind of this-earthly achievement. But, the change in the attitude of humans and the deterioration in the standard of their lives in the present century have drawn his attention. He, who has great concern for society's 'impending collapse,' states: "It is not the dramatist's task to create confrontation or chaos, but rather, to create order The entropy, the drama continues until a disordered state has been brought to rest" (Brewer 1993). This consciousness for orderliness is one of the central themes of Mamet's plays.

Life is full of pleasant surprises and shocking realities. It is because of these, life remains interesting and worth living. According to Mamet, "The purpose of the theater is not to deepen the mysteries of life, but to celebrate the mysteries of life and also to address the questions of 'What is our place in the universe?' and 'How can we live in a world in which we know we're going to die?'" (Nuwer 2001). A life well-lived has a peaceful end. Hence, humans should take care to lead a meaningful life. This attitude to life, makes Mamet and his writings humanistic. The playwright determines the initial disorder only to lead it to resolution. He, who believes in humanity's power to create their own happiness, also enjoys the thrill in holding a power over his actions. His statement: "I like to make decisions, and I like to be at the center of things," (Brewer 1993) establishes him as a maker of his own paths and as a human being, who considers that he is responsible for his own actions.

Mamet's 'Reunion' has been taken up for the present study to bring out his humanistic vision. The portrayal of characters, sequential happening of events that constitute the story line and the language that is used to bring to the





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forefront the nature and the attitude of the Americans, especially the middle class Americans – all these show not only Mamet's creative thinking, but also his concern for the welfare of the people. The dramatist is affirmative about the positive changes in the future world. When asked what his response was to this hostile and absurd world, Mamet answers, "Tolstoy said it's a mistake to think that human nature ever changes. This is the only world that I live in, so (a) it would be silly for me to say something else because it isn't something else; and (b) I am part of it" (Roudane 2001). It is this sense of belongingness that makes Mamet accept the world for what it is and remain positive when things go astray and awry. As a humanist, he tries to convey the message that human beings can and must be happy in this one and only world during their one and only life. And also, he discusses the ways through which this happy end can be achieved.

HUMANISM IN 'REUNION'

'Reunion'(RU) produced in 1976, is about the reunion of a father and a daughter after twenty years of separation. The play's philosophy is that human beings need life-long companions to lead a happy and contented life. Carol, who has got separated from her father, because he has divorced his wife, comes back to renew her relationship with her father. Meanwhile, she who has been living with her mother, after the parents' separation, gets married, but gets separated from her first husband after some time to marry another person called Gerry with whom she lives with Gerry's kids. Though she is not fully satisfied with the kind of life she is living with him, she says that they get along with each other. The father and the daughter discuss all that have happened during the years of separation and hope to have happy years ahead in their reunion.

At the surface level, the play shows the reunion between an ex-alcoholic father and his daughter. But, for Bernie, the father, it is a reunion with his life, a new one, which he is going to start at his fifty-third year. The play also states that humans, as social beings, should not only pursue happiness, but also spread it. Another important and relevant humanistic credo the play deals with is the individual's and the society's responsibility in improving the happiness, especially in families. The diminishing living standards have resulted in humanity's poor perception of the value of happiness. 'RU' upholds the worthiness of happiness which is directly proportionate to the right standard of living.

In 'RU,' Bernie, who wants to present himself as a transformed personality, tells Carol that he does not consume alcohol. He tells her about his attempts to keep his house neat:

If I was still drinking, I'd offer you a drink

If I was still drinking, you probably wouldn't be here ...

(Mamet 1979a).

In all these, Bernie is projected as a father who is welcoming the daughter heartily. He, who has undergone the torments of a broken marriage and experienced quite a lot of displeasure in the remarriage, has great concern for his daughter's happiness in her second marriage. Carol tells him that though Gerry loves her, he looks frightened. She also tells him that since Gerry is a 'lousy' person, they do not enjoy marital bliss. On hearing this, Bernie offers her words of consolation like a responsible father.

Bernie regrets for wasting his life in the past by consuming liquor always. But, the spirit of humanism lies in realizing and rectifying one's mistakes. There is no age limit for correcting one's errors. At the age of fifty, he says that he wants to lead a fresh life and pursue happiness: "But I'm a happy man now. And I don't use the term loosely. I got a good job at the restaurant. I've stopped drinking. I'm putting a little money away For the first time in a long time I got a kick out of what I'm doing. I enjoy it at work. Everybody knows me. They respect me" (Mamet 1979a). As a humanist, he measures his happiness with the standards of right living. He seems to have realized the value of being respected by fellow beings.

As a father, Bernie wants to inculcate the spirit of living in Carol. He failed to inspire her when Carol was young because he was not an exemplary father then. Now, he considers it his duty to encourage and support Carol. He says





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What have you got to lose?
 Take a chance
 You got to take your chance for happiness
 You got to grab it
 You got to know it and you got to want it
 And you got to take it
 Because all the possessions in the world can't take it for you (Mamet 1979a).

Every human has a right to be happy. As Renuga et al. (2022) state, “the world always presents the humans with challenges and the human kind, using the available resources in the form of experiences and rational thinking, tries to offer solutions and overcome struggles”. Good things may come to those who wait, but the best comes to those who grab the right opportunity at the right moment and make it their own. Bernie wants Carol to get the better of her struggles and create an opportunity to be happy. He is now able to give the consolation and companionship to Carol that she needs. She has come back to him after twenty years only for this.

In his ‘Forbidden Fruit: The Ethics of Humanism,’ Kurtz (1988) says, “More fundamentally, parents are responsible for bringing up their children. They have a moral obligation to protect them by providing adequate food, shelter, and health care and making available opportunities for learning.” Bernie realizes that he has not done his duty to Carol and that he has deprived her of a happy childhood because of his divorce from his first wife. When he reminds her of the few happy moments of the past, there is actually an underlying regret that he has been responsible for her missing a standard and happy childhood. To make up for the loss, he reminds her of the happiness that prevailed in the family. By describing the happiness of having a child as ‘indescribable,’ he actually insists that he has always considered her a treasure. He says:

Having kids, Carol, is something no one can describe
 Having your own kids is Indescribable
 You were a little kid.
 We used to have a good time
 Going to zoo ,.....
 You were a beautiful kid.
 You were everything to your mother and me (Mamet 1979a).

Bernie implies that she can get rid of the dissatisfaction she is feeling in her life now by having her own child. He also wants Carol to feel the happiness that he is enjoying on seeing Carol.

The play is partly autobiographical. The reunion in the play reminds one of the playwright’s reunions with his father after some years of his stay with his mother after her divorce from Mamet’s father. The father of this play is the namesake of his own father Bernie Mamet. Mamet himself, as a child of separated parents, has never had a happy childhood as he recalls, “My Childhood, like many people’s, was not a bundle of laughs” (Lahr 1997). One of the reasons for the crumbling American society is lack of intimacy, among family members, which, as society advances, proportionately increases. Carol says,

When I was young they used to talk about Broken Homes
 Today, nothing. Everyone’s divorced.
 Every kid on the block’s got three sets of parents
 But It’s got to have affected my marriage.
 I come from a Broken Home
 The most important institution in America (Mamet 1979a).

Carol relates the failure of her first marriage to the increase in the number of broken marriages in the neighborhood. As she rightly puts, the separation of her parents has influenced her married life and led to its failure. Bernie feels





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that the society and the Government, in a way, are responsible for such broken families. Bernie says, "I was mad at the fucking government that never treated me like anything but a little kid saving their ass with day light precision bombing (Mamet 1979a). He observes that his Government's insistence on waging war to improve or show its power has made him lose sight of the happiness in a healthy family.

Mamet attests to this view, because when he began writing in 1970s, as Bigsby states, there was an air of ambiguity in the society. The society had just faced a war, which killed 50,000 Americans, because of Kennedy's misplaced commitment, corruption on the part of a Vice-President and an era of poverty resulting in a 'me' decade (Bigsby 2000), where social values were considered out-dated. With this confused state of affairs, the American society has nothing to offer to improve the people's feeling of worthiness in living. Mamet also stresses the need for the individual's responsibility to redeem the situation. Since individuals make a society, the change in each individual will lead to reformation in the society. Hence, Mamet brings in the transformation in Bernie. The line "The actions are important / The present is important" (Mamet 1979a), shows the significance of leading a meaningful life in the present. When a person starts realizing the importance of the present and value of time that flies, the chances for him to waste both his and others' lives become less. It remains all the more assured that he or she will live the right kind of life.

Carol has sought Bernie, "to find a father, a source or emblem of support in her inner isolation" (Clurman 1979). It is the trust in her father that has made her come back to Bernie. She does not see him as a friend, but wants him to be her father. She says, "And I don't want to be pals and buddies; I want you to be my father" (Mamet 1979a). Bernie feels really happy that he has got an opportunity to bring happiness into his daughter's life. This time, he is sure to do his duty to his own satisfaction and meet the expectations of Carol.

Bernie : You know what the important thing is?
 Carol : What?
 Bernie : To be together.
 What's past is in the past it's gone.
 You're a grown woman I'm on the wagon,
 Your mother's remarried. I got a good job, and there's no reason
 I can't make it up to you (Mamet 1979a).

He takes care to know whether his remarriage will affect Carol. Carol is equally interested in his happiness and is happy about her father's remarriage.

As in Mamet's 'The Woods'(1979b) here, too, a bracelet acts as a symbol of reunion and reconciliation. Bernie presents Carol with a bracelet. She accepts the bracelet from Bernie and the bond between the father and the daughter is strengthened as it does between the lovers in 'The Woods' (1979b). Commenting on the reunion, Clurman (1979) states, "Both she and her father are more or less unconsciously yearning to provide some special service to the other – an affection, tie, a solace which they timely hope will strengthen in time." A relationship, which is nurtured by mutual sharing of love and affection, will remain an everlasting one. 'Reunion' emphasizes the invaluable relation in the lives of humans. It also highlights the need for a filial companionship. It stresses the need for the society to play an active role in fine-tuning the life style of its people. Thus, the play establishes Mamet as a humanistic thinker.

The strength of a writer lies in the way he instills hope in the readers or audience. 'Dark Pony', which is examined next, is one such play where Mamet eases away humans' restlessness and pain by pinpointing the fact that human sufferings are shortlived.



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CONCLUSIONS

Thus 'Reunion' underscores the humanistic philosophy of life-long companionship which is essential for a happy and secure life. It highlights the importance of the individual's and the society's responsibility in improving the happiness in families. It brings together a father and a daughter, who have been separated for several years. Like 'The Woods' (1979), it stresses the fact that emotional understanding is necessary to nourish and strengthen the bond among human beings.

REFERENCES

1. Bharathi S. (1937), 'Essays and Other Prose Fragments,' Eds., C.R. Reddy and K.S. Venkataramani, Bharathi Publications, Chennai.
2. Bigsby C W E. (1985), 'David Mamet,' Methuen, London and New York.
3. Brewer G. (1993), 'David Mamet and Film: Illusion / Disillusion in a Wounded Land,' McFarland and Company, Inc., Publishers, North Carolina.
4. Bullock A. (1985), 'The Humanist Tradition in the West,' W.W.Norton and Company, New York and London.
5. Clurman H. (1979), 'Reunion, Sanctity of Marriage, Dark Pony,' Nation, 1 December, pp. 571 -72.
6. Devaraja N K. (1988), 'Humanism in Indian Thought,' Indus Publishing Company, New Delhi.
7. Flynn J R. (1973), 'Humanism and Ideology,' Routledge & Kegan Paul, London and Boston.
8. Hornby A S. (2005), 'New Oxford Advanced Learner's Dictionary,' Ed., Sally Wehmeier, Oxford University Press, Oxford.
9. Karnad G. Tr., (2000), 'Hayavadana,' in Modern Indian Drama – An Anthology, Ed., G.P.Deshpande, SahityaAkademi, New Delhi.
10. Kroll J. (1977), 'The Muzak Man,' News Week, 28 February, pp. 79.
11. Kurtz P. (1988), 'Forbidden Fruit: The Ethics of Humanism,' Prometheus Books, New York.
12. Kurtz P. (1974), 'The Fullness of Life,' Horizon Press, New York.
13. Lamont C. (1997), 'The Philosophy of Humanism,' Humanist Press, New York.
14. Lahr J. (1997), 'Profile: Fortress Mamet,' New Yorker, 17 Nov., pp.70-82.
15. Mamet D. (1999), 'True and False: Heresy and Common Sense for the Actor,' Vintage Books, New York.
16. Mamet D. (1979a), 'Reunion,' Grove Weidenfield, New York.
17. Mamet D. (1979b), 'The Woods,' Grove Press, New York.
18. Renuga M, Kanchanamala B &Saraswathy M. (2022), "A Scientific Approach to a Meaningful Life: A Study on Humanism in Mamet's Select Plays," Neuroquantology, Vol. 20, pp 5038 – 5048.
19. Roudane M C. (2001), 'Something out of Nothing,' in David Mamet in conversation, Ed., Lielie Kane, The University of Michigan Press, Ann Arbor / US.
20. Tagore R. (1990), 'Chandalika,' in Three Plays: Mukta-dhara, Natir Puja, Chandalika, Tr., Marjorie Sykes, Oxford University Press, Madras.





Identity and Alienation in Chitra Banerjee Divakaruni's *Oleander Girl*

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ABSTRACT

Chitra Banerjee Divakaruni a multicultural, post-colonial diasporic Indian living in US is one of the most influential contemporary Indian novelists in Indian English writing. Her works distinctively occupy an enduring place in the Indian scenario among the cosmos of women writers. She has curtailed the requisite deep-seated anguish and apprehension of displaced women in her novels. Her creations demonstrate Indian women as supreme characters. The voice of Indian woman speaks in many languages, each having a rich regional flavour of its own. Divakaruni by demonstrating female-narrative throughout her works, has made an entreaty for a better livelihood of women, sustaining their resilience. One of the major themes of her novels is transcending boundaries. This paper attempts to analyse the exile aspects widespread in the novel *Oleander Girl* which further leads to the development of transcultural identities of the protagonists.

Key words: Identity, Exile, Culture, Diaspora, Transcultural, Alienation

INTRODUCTION

In the era of globalization, immigration has become a vital phase in human fortitude. Historical, linguistic, and anthropological approaches embraced by a choice of researchers in the past have helped in studying the pattern of migration and this has steadily created a place in literature. Culture is an indispensable element of human life. There are two important aspects which need to be remembered about cultures. They constantly vary and also relate to the symbolic facet of life. Human behaviour vastly varies, and the variations are necessarily determined by culture. According to Trompenaars, "Culture, is [also] the way in which, a group of people solve problems, and reconcile their dilemmas" (6). No individual can acquire culture without communication and relations. It is exhibited in the facade of customs, attitude, ideas and ethics that is pooled by people of a faction or society. Culture is vibrant and





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ever changing. Thus, culture is unquestionably a part of any society and incessantly evolves out of society in a different mode. Literature shapes and changes the social thoughts and makes its readers more insightful to others' position in social culture.

Literature of Diaspora holds a striking locale between cultures and zones. It creates theory and identifies positions as it shapes new identities which surmounts limits and precincts, relating to diverse sequential and spatial descriptions. Because of the ongoing changes, confluence of cultures and intersection of identities a novel theory diaspora emerged in the academic field and literature. The deep-rooted mixed feelings, sense of belonging coupled with loss, an aspiration to conform to the pattern of living and also an inclination in contributing towards the progress of the people living in diaspora created an expression in a new academic discipline known as the diaspora studies. As the immigrants are able to take in the pre-eminence of both the native and alien culture, they foster themselves into international citizens. Thus emerges an immigrant literature as a part of migration.

Diaspora literature explores the basic questions of identity, home, culture, memory, space, nation, belongingness, assimilation, acculturation and transmutation. Bill Ashcroft, Gareth Griffiths and Helen Tiffin in *Key Concepts in Postcolonial Studies* label 'diaspora' as "The voluntary or forcible movement of people from their homelands into new regions..." (68). Dislocation creates an extraordinary impact on migrants, and it takes many forms like migration, exile and diaspora where the movement is either forced or voluntary. Exile and displacement due to migration are incredible contemporary realities that have manipulated the imaginary realm of fiction. Chitra Banerjee Divakaruni, an Indo-American writer has portrayed women characters in her novels through her social observation and experience. She constantly focuses her writing on women issues like identity crisis and how they later discover themselves though disenchanted in various cultural conflicts.

Divakaruni focuses on the confrontation women combat, both in India and the United States as the condition of migrants' lives are transmuting, and so are the approaches adopted by them to surmount the dislocation trauma. She says:

Actually, though I think of my female protagonists having both strengths and weaknesses. They are complex characters; they often make wrong decisions; this is as true of Korobi in *Oleander Girl*. Perhaps what distinguishes my character is their courage and spirit and a certain stubbornness which enables them to keep going even facing a setback. I think it developed organically as I wrote but also it came out of a desire to portray women as powerful and intelligent forces in the world." (Times of India, May 6 2013)

When individuals or a group of individuals willingly migrate to reconcile in another part of the globe, they choose to migrate with a purpose that fosters dreams in their minds -dreams of an enhanced life and a place that would entrancingly revolutionize their state of endurance and give them a superior identity. In one's interaction with migrant literature, one experiences 'displacement' not just spatially but also from geographical paradigms, where the quintessential facets of human migration include- the migrant dreams, the desire to escape, forced migration, exile, coping with the distance, existing between times and spaces and nostalgia.

Divakaruni's writing focuses on the need for the creation of new spaces which permit people to cross borders in search of democracy, justice and social engagement. Lisa Lau observes that, "Although all the debut novels and short stories [on the list she provided] have located their plots and characters in South Asia, Divakaruni... did not choose to do so" and instead focused on "writing of the diasporic experience for South Asians in USA" (241).

Chitra Banerjee's writings are chiefly based on poignant crisis, imagination and the substantial strife of Indian immigrant women who desire for belongingness with the indigenous culture and idealism. She uniquely strategizes the image of ordeal women preoccupied with their inner world, their brooding resentment and the storm within the pragmatic dilemma of womenfolk in a male subjugated society. In her novels there is an endeavour to understand the inner aspect of the female characters and to study their position in a society over-ridden by androcentric norms. She says, "Women in particular responded to my work because I'm writing about them- women in love, in





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difficulties, women in relationships. I want people to relate to my characters, to feel their joy and pain, because it will be harder to [be] prejudiced when they meet them in real life" (Softky).

A woman has to cross several boundaries right from her birth to her matrimony and this novel *Oleander Girl* depicts a similar expedition of the protagonists Korobi and her mother Anu. The novel also delves into the concise images of how women are trapped between the ethics of the old and the new world. It draws attention on how women deal with cross-cultural relationships; accomplish self-esteem and autonomy deprived to them within their own tapered and opinionated community. America has become the connoisseur for people all over the world. Immigrants, who become part of the American culture, integrate the paraphernalia of their own traditions which in turn transforms their culture too.

The novel *Oleander Girl* is set in India. This novel portrays women belonging to three generations- Korobi, her mother- Anu, and grandmother- Sarojini. Every generation has different idiosyncratic women folk involvements and encounters. Korobi, orphaned at a young age is raised by her beloved grandparents Sarojini and Bimal Roy. Throughout her childhood days she longs for her parent's love that she never experiences. "...All through my years growing up, I longed for a visitation from my mother.... I prayed for it in secret, and, when that didn't work, tried to put myself in calamity's way.... But only ended up with bruises, sprains..." (Divakaruni2). One morning she visualizes her mother Anu's shadow in her dream. She says, "From time to time, I imagined- a mix of horror and pride- what Grandfather's reaction would be when he saw me in it." (OG18). Though Korobi intends to discern much about her parents she doesn't investigate, as it would be excruciating for her grandparents.

Divakaruni deliberately exhibits a factual portrait of the Indian society where Anu becomes a victim of the Indian concept in doing something right or wrong. Because of her bleak experience she becomes quiet forever creating a dreadful memory throughout the narrative. She passively prevails in the whole story. Korobi in spite of being obdurate with independent thoughts and consciousness about self, hesitates to upset or disobey her grandfather who rules the family, with iron fist, like Chitra Divakaruni's father. Korobi's grandfather is a conformist, patriarchal, conservative attitude who relishes an exquisite life, secedes a daughter from her parents and keeps a father away from his child for years. Sarojini represents a rudimentary personality. It is she who endures from Identity Crisis and psychological alienation due to Anu's migration.

Korobi gets highly distressed and absolutely lost when she happens to realize that she is the daughter of an Afro-American. Her identity which, is entwined with the status of the Roy family, is shattered. Like any other women character in Divakaruni's novels, Korobi is cognisant about herself. It is an issue of her being illegitimate, which makes her feel disgusting. "I'm illegitimate? I whisper....I'm a ----- bastard? I can't come to terms with this new, shameful me" (OG 245). It is observed that Korobi's panic and ordeal of being illegitimate is solely positioned on stereotyped Indian ethnicity in which such illegitimacy is enormously surmounted. Korobi's mother Anu's, means of displacement, both culturally and geographically is the cause behind this.

Korobi plans to leave for America to discover her dad and her self-identity. Jasbir Jain opines, "Migrations are themselves as ancient as known histories – whether we refer to the biblical journeys or the travels motivated by adventure, lure of wealth, search for land or power" (248). Korobi escapes from India to get rid of her subjugated position. Critic Said asserts:

Exiles, unlike travellers, bear the mark of history in their personal narratives of loss and thus desire the stability of belonging, but that belonging must come as the result of critical, affiliative efforts to participate in collectivities. The image of exile theorized and embodied in Said's work presents us with a model of an affirmative, though not unlimited, version of human agency based in the traumatic experience of loss that is the beginning of exile. (34)





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Korobi finds it hard to commence a new life with Rajat to whom she is engaged. Rajat expresses his insightful love and strong belief on her. He exclaims that he is more concerned with the present than the past and the future. Korobi still remains obdurate and declares:

Rajat you don't understand! I don't want it to fade away. I'm shocked and hurt, yes, but I'm excited, too. Do you see? I have a father now! I can meet the man my mother loved so much! All my life I longed to understand my parents. Now fate has given me a chance. (OG 67)

Korobi determined to find her father says, "Until I find him Rajat, I am not sure I can get married" (OG 67). Rajat persuades Korobi elucidating regarding the less possibilities in locating her father. But she still says, "I don't care!" (OG71). "I'm even prepared to go to America" (OG 72). Well aware of all the hardships and bad luck on the way, like any other immigrant Korobi plans to forego her diplomatic and tenable Kolkata way of living. She gears up to forfeit her dear ones and chooses a challenging path in search of her identity. In spite of such experiences being taxing, they also endow with suitable circumstances for creating a 'new identity'. It is Sarojini, her grandmother, the very expression of tradition, who has faith in her. Korobi's exile from India is to purge her subjugated position and to confront the prophetic curse, likely on her.

Other than Mitra, many other characters have been influential in transforming Korobi into a resilient person. When Korobi lands in America experiences get engulfed on her way. When a tramp, with a tonsured head advances her with hands outstretched, she yells, "Go away! Stop harassing me!" (Divakaruni14). This petite triumph is formidable enough to make Korobi realize how to stand on her own, poised and valiant.

Even the disasters and distresses, that Korobi faces while hunting her father, changes her to heroically take life in her stride out. At the end of the novel, we learn that Korobi has grown into a stabilized individual - a perfect Oleander girl. She asserts "I'm Korobi, Oleander, capable of surviving drought and frost..." (274) even though she had to journey through miseries as no detours are feasible. It is the superfluous love rather "a conspiracy of love" (280) between Rajat and Korobi that triumphs over antagonism and delusion. Divakaruni has skillfully depicted the different facets of Korobi's traits.

When interviewed by Debby De Rosa Divakaruni replied as:

The oleander seems to be the perfect symbol for the book on many levels. It is ambiguous, positive, and negative, beautiful and dangerous- and hardy, capable of protecting itself. It is central to the mystery of the protagonist Korobi's mother Anu, because Anu (dying at childbirth) chooses to name her daughter after this complicated flower. A question that drives the novel is why Anu chooses to name her daughter after this flower. Why not Rose or Jasmine or Lily, as is more common? It is also a flower that grows in both India and America, connecting the two worlds through which the novel and our protagonist travel.

Hamid Naficy's concept of liminality can be used to examine exile cultural production in Divakaruni's protagonists. He pronounces the state of exile as "a process of perpetual becoming, involving separation from home, a period of liminality and in-betweenness that can be temporary or permanent, and assimilation into the dominant host society that can be partial or complete" (6). He stresses that the, "state of exile is to be in neither one place nor the other, but to be in-between, to be "travelling in the 'slip zone' of fusion and admixture" (8). Exile is, therefore, not just a state of dystopia and dysphoria, but is competent of productivity as well, as annihilating one set of codes and replacing them with altered sets of unification inscriptions. From this process, exile culture is shaped and becomes an imperative mode of negotiating codes, inscriptions, and identities.

Naficy claims, that the exilic peril has effectively been resolved, to create 'new improvised' identities with ethnicity. Similarly it is Korobi's conscious effort to eliminate everything that hampers the growth of her original 'self'.





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The decision of Korobi to leave her motherland and go to a foreign land is influenced by many push and pull factors. An analysis of these factors is imperative as they determine whether her migration was voluntary or involuntary. Korobi in order to recreate her autonomous existence migrates to America. Jasbir Jain makes an observation:

Diasporic presence is dispersal, a scattering, a flight and has to take root elsewhere, especially if it seeks sustenance and growth. But it continues to depend on the bits and pieces of its origin to hold itself together in the face of the onslaught, rejection or domination by the 'other', by the world which both frightens and fascinates too. Whatever mode it adopts and temporalities it relates to, is still primarily concerned with the contingent of being. (79)

Chitra Banerjee through her character Anu propounds how exile is, as prevailing as Diaspora which gives migrants an opportunity to excel in their career. Her protagonists pursue to amalgamate tradition with the contemporary values which is the need of the hour. Like any other migrant Korobi too migrates away from the extravagance of life and determines to stride out in the path to destitution and assertion, with the anticipation of attaining her original identity. Her hunt for her father which got her to America, had altered Korobi into a secure woman – "...beautiful – but also tough" (Divakaruni 253) like the Oleanders.

Edward Said perceives the romantic notion of exile as a heroic tale where characters are exalted and portrayed as enchanting people who continue to exist in the new land. The expedition of an emigrant from being independent in profundity of their barrier into shinning as an entity is very atypical. Divakaruni does offer empowerment to women of diaspora on various levels, including camaraderie with other women, response of their encouragement, and curative role which they often play individually and reciprocally among themselves. Instead of the negative 'push' factor it is the 'pull' factor which is largely the motivation for migration in her novels. Though the protagonists transpose from one nation to another they are struck by the reforms in everyday realities, but the hindering experiences are transformed into reassuring certainties. 'Past' becomes an optimistic stimulant and it serves to reformulate and change the present. Push and pull between tradition and modernity and expectations and aspirations too can be observed.

Women are on exile for various reasons like marriage, profession, and better prospective. In general people by moving and trans-locating, have enriched the society which gives rise to assimilation, absorption and incorporation. Liberation for women lies in their ability to comprehend themselves, as well as to endure sisterhood with their own gender to tussle against the domination of patriarchal ideology and humanity. Divakaruni's opinion is that adaptation and synthesis will enable the survival and progress of the immigrants in the diasporic location. Immigration provides relief and redemption to them. Diaspora thus experiences various kinds of displacement, but it is their inner consciousness which makes them adjust, accommodate and even adapt. Qualms, despondence, conflicts, fears and distrust characterize the people who reposition to new places, but their struggles are testimonies of chronicles time which furnish towards amelioration of their self-perception in accord with their past and memories.

Exile can arise in a homeland due to modernization which can cut off a person from his traditional language, religion, cultural practices, and way of life. It serves as a reason for the individuals to get dislocated and migrate to different countries for diverse intentions.

Dislocation today is ascribed and substantiated as the distinctive feature of humanity and not just a feature of the Diasporas alone. It implies crossing of borders and boundaries, moving from one culture to another. It entails a break of the old identity and the creation of a new identity. A life of exile, immigration and voyage shapes one's individuality. Identity is vital for ensuing triumph of self-actualization. We inreich explains,

A person's identity is defined as the totality of one's self-construal, in which how one construes oneself in the present expresses the continuity between how one construes oneself as one was in the past and how one construes oneself as one aspires to be in the future"; this allows for definitions of aspects of identity, such as: "One's ethnic identity is defined as that part of the totality of one's self-construal made up of those





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dimensions that express the continuity between one's construal of past ancestry and one's future aspirations in relation to ethnicity" (Weinreich, 1986)

Dislocation, thus, in Divakaruni's novels resulting due to exile, migration or immigration, offers her protagonists the possibility of equipping constructive spaces for assimilation. The inspiration of liberty is steadily achieved in the foreign land, but the exile has to prevail through several barriers to attain the phase of mental independence. Exile also largely offers a probability for growth and cross-cultural ambivalence resulting both in alienation and assimilation. The uncovering of characters to contradictory cultures helps the protagonists in overcoming the barriers and facilitates them to undergo trans culturalism - the creation of new identities. Though there is very less scope in patriarchal Indian communal set up to acclaim a uniqueness, Chitra Banerjee has created women, who re-discover themselves filling the void space by putting an end to the customs and traditions.

REFERENCES

1. Ashcroft, Bill, Gareth Griffiths, and Helen Tiffin. *Key Concepts in Post-Colonial Studies*, London and New York: Routledge, 1998, pp. 68-70.
2. Banu, C. Shahin. *Excruciation and Endurance in the Select works of Rohinton Mistry*.2021,Periyar University. Ph.D. dissertation.
3. Divakaruni, Chitra Banerjee. *Oleander Girl*. New Delhi: Penguin Book India, 2013. Print. Hamid, Naficy, The Making of Exile Cultures: Iranian Television in Los Angeles (Minneapolis, 1993). *Iranian Studies*, Vol 39, no. 3, September 2006, p.6-9
4. "Interview with the author of *Oleander Girl*" DeRosa, Debby. 28 March, 2013. Web. 10 July, 2015.
5. Jain, Jasbir. *The Diaspora Writes Home: Subcontinental Narratives*. Jaipur: Rawat, 2015, p.248.
6. ---. "The New Parochialism: Homeland in the Writing of the Indian Diaspora." *In Diaspora. In Diaspora: Theories, Histories, Texts*. Ed. Makarand Paranjape. New Delhi: Indialog, 2001, pp.79-92.
7. Lakshmi G . Saratha. *Emergence of Autonomous Self through Predicaments in the Select Novels of Shashi Deshpande*. 2021,Periyar University. Ph.D. dissertation.
8. Lau, Lisa. "Making the Difference: The Differing Presentations and Representations of South Asia in the Contemporary Fiction of Home and Diasporic South Asian Women Writers." *Modern Asian Studies*. 39, 2005, pp.237-257.
9. Said. *Culture and imperialism*, Vintage publishers. 005, 1993, p.34.
10. Softky, Elizabeath. (2007). A Cross Cultural Understanding Spiced With the Indian Diaspora. <http://diverseeducation.com/article/8312/> Accessed on 14 Feb 2017.
11. Times of India. 6 May, 2013.
12. Trompenaars, F., & Hampden-Turner, C. (1998). *Riding the waves of culture: Understanding diversity in global business*. McGraw Hill.
13. Weinreich, P. (1986). *The operationalization of identity theory in racial and ethnic relations*. In J.Rex and D.Mason (eds). *Theories of Race and Ethnic Relations*. Cambridge: Cambridge University Press.





Prevalence of Optimism in Mother- Child Relationships in the Novel the Binding Vine by Shashi Deshpande

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ABSTRACT

The Study recounts the analysis of maternal bond that provides psychological, social and physical security to children. There is sob and smile, separation and reconciliation, affection and abhorrence, problem and remedy in every family. However, mothers in a family must have love and be considerate towards their children and must demonstrate interest in their children's happiness and merits. Shashi Deshpande is a realistic writer who effectively deals with the practicalities of mother-child relationships and also about the evolution process that changes the relationship to be optimistic. Therefore the study underscores the prominence of mother's love and her presence in the family to create an optimistic atmosphere.

Keywords: maternal bond, blessing, hope, confidence, sacrifice .

INTRODUCTION

A maternal bond provides psychological, social and physical security to children, which is why children and mothers become more emotionally attached to each other. Shashi Deshpande professes in *Moving On*: "The umbilical cord continues to exist, a phantom link, all our lives. We can never deny the ties of the body; we can never leave them behind us. The ties we forge through our bodies are the strongest, the hardest to sever. Look at the way we connect the organs of the body to the emotions and feelings" (MO114). Urmi, the protagonist of the novel *The Binding Vine*, leads a miserable life due to the demise of her daughter Anu. Shakutai, a poor mother sacrifices her life for her daughter's health and economic well-being. Vanaa, friend of Urmi works very hard in order to take care of her





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children and Mira, Urmi's mother-in-law sacrifices her writing skills for her children. The title *The Binding Vine* authenticates that love and hate, and sorrow and joy are inexorable in mother-child relationships.

Urmi's daughter, Anu, in *The Binding Vine* dies when she is very young. Urmi feels isolated and is unable to forget her baby's soft snuffling sound, sweet milky ammoniac talcum odours, and the toes that fumbled at her midriff. She carries the sovereign air of despair throughout her life. She professes: "I can smell her sweet body flesh ...my breasts feel heavy and painful, as if they are gorged with milk. I can feel her toes scrabbling at my midriff" (TBV 21). Urmi leads her life in emptiness and proclaims, "as if the core of me has been scooped out, leaving a hallow" (TBV 17). Urmi suffers gravely in the process of accepting her daughter's death that makes her sense the loss of everything in life. Researchers Arnold and Gemma advocate in *Healing Hearts*:

Children are not supposed to die ...parents expect to see their children grow and mature. Ultimately, parents expect themselves to die and leave their children behind ...This is the natural course of life events, the life cycle continuing as it should. The loss of child is the loss of innocence, the death of the most vulnerable and dependent. The death of a child signifies the loss of the future, of hopes and dreams, of new strength and of perfection. (IV 9, 39). Therefore, it is obvious that most of the parents' dream is to live merely for the welfare of their children and they also lose their personal desires and aims for the well-being of their children.

Like the authors express, Urmi also believes that her future lies in the memories of her daughter and it is inhuman to forget her baby. She opines: "I have no desire to leap into future, either to project myself into a time when all this pain will be a thing of the past, healed and forgotten. This pain is all that's left to me of her; I will lose her entirely" (TBV 9). It is always thought that the loss of a child will lead to a mother's mental illness, the emotional blow associated with childless can lead to a wide range of psychological and physiological problems including depression, anxiety, cognitive and physical symptoms linked to stress, marital problems, increased risk of suicide, pain and guilt. Though Urmi is stressed, she tries hard to console herself by recollecting the joyful days that she spent with her daughter and also cognises the problems of her relatives and friends and directs her energy completely in helping them find solutions for their problems. Thus, ShashiDeshpande advocates to the readers through Urmi that mothers should care and love their children. Indeed, the love that mothers shower on their children must not get depleted as it is necessary to create unquantifiable amount of human goodness in the family.

Inni, the mother of Urmi, asks Urmi to hang the photo of Anu on the wall. Urmi gets wild and replies: "I don't need a picture to remember her, I can remember every moment of her life. How can you imagine I need a picture?" (TBV68). Urmi recalls her daughter's journey with her every now and then and she believes subconsciously that Anu is alive and it is this hope that makes her face the world with confidence. As Emily Dickinson, an American poet says: "Hope is the thing with feather/ That perches in the soul / And sings the tune without the words / And never stops at all" (1-4). Only the memories of her daughter give Urmi hope to survive. Kate Stone Lombardi, who is the recipient of six clarion awards, advocates in *The Mama's Boy Myth*: "a healthy, loving relationship is one in which mom is emotionally supportive of her son and she should realise and recognise his individuality, sensitivity, uniqueness and also his vulnerability along with his strength" (121). So the mothers' responsibility is to understand their children well and to contribute to the growth of their children.

Urmi proves to be the best mother for her son, Kartik. She takes care of him so well. The mother and the son understand each other well. For example, Urmi reaches home very late from Shakutai's house that makes Kartik worry so much and makes him wait for a long time with an empty stomach for his mother to join him for dinner. Urmi comprehends the expectations of her son inordinately. She opines: "I cannot wrong him. I must let Anu go. I know nothing can undo what's happened, nothing can bring Anu back to me. And I know I have to go back to living" (TBV22). She keeps encouraging her son Kartik in all his accomplishments. Urmi can be compared to Nancy Matthews Elliott, the mother of the great scientist Thomas Alva Edison. Once Thomas Alva Edison brought home a letter from his teacher and asks his mother to read it for him. The mother read the letter which said: "Your son is a genius. This school is too small for him and doesn't have good enough teachers to train him. Please teach him





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yourself". So Edison's mother gifts him a fundamental book on experiments in Chemistry and keeps encouraging him in all his experiments. Later, in his life, after his mother's demise, he finds the old letter from his teacher which states: "Your son is mentally deficient. We cannot let him attend our school anymore. He is expelled." Stirred by the encouragement and the optimistic attitude that his mother has given him and he mentions in his diary: "Thomas A. Edison was a mentally deficient child whose mother turned him into the genius of the century." He feels so proud to say that his mother changed his destiny. He expresses: "Mymother was the making of me. She was so true, so sure of me, and I felt I had someone to live for, someone I must not disappoint" (Qtd. in Crane 24). Likewise, Urmi's son Kartik also carries unconditional love and respect for his mother like how Edison loved.

Mira, the mother-in-law of Urmi, asks her mother to do a study on her horoscope but her mother refuses and replies: "What's there in my life apart from all of you? If I know all of you are well and happy, I am happy too" (TBV101). Most of the parents lead their life only for the happiness and for the benefits of their children. Mira gets married at the age of eighteen; her husband belittles her every now and then, but she tolerates everything for her unborn son. Her love for her son is revealed in her poems. She asserts:

Tiny fish swimming in the ocean of my womb
my body thrills to you;
Churning the ocean, shaking distant shores
you will emerge one day
Lightning flashed through the front door
and I who was stone quivered.
Bridging the two worlds, you awaken in me
a desire for life. (TBV136).

It is very through the poem that Mira adores her son and enjoys every movement of his in her womb and it is these to and fro movements of her baby that makes her crave for a happy life. She dreams to take care of the baby with utmost love.

ShashiDeshpande conveys the importance of love and care that mothers should carry in them for their children through her characters: Urmi, sakutai, Vanaa and Mira. They ingrain in the minds of the readers that encouragement and guidance by parents will help in bringing positive changes in children and will also help them in leading a successful life.

Misunderstanding between parents and children is a common issue in most of the families, and so efforts must be taken by both to have a better understanding. They must have respect for each other's views and for their contributions to the family. Urmi misapprehends that it is her mother who has sent her to Ranidurg, the place where her grandparent's reside and assumes that her mother is the main cause for her sufferings during her childhood days. She says that she felt like an orphan without her parent's love. Her suffering is similar to Maya, the protagonist of the novel *Cry the Peacock* by Anita Desai. Maya remains as a motherless child and she wishes someone to replace her mother. She says:

I could not remember my own mother at all. My throat
Began to swell with unbearable self-pity. I could cry, I
Knew it, in a while, and dreaded it, in their sane,
Presence, 'please 'I whispered.' (163)

Similarly, Urmi also yearns to be accompanied by her mother when she is young, but her mother fails to do it. So she does not possess any distinct reminiscence of her mother's care or love when she grows up. But she never fails to respect and love her mother and she also learns to shower her love over her son Kartik. Sally Garatt propounds in the book *Women Managing for the Millennium*: "Having learned from the past and present, women can approach the future confidently knowing what challenges they will have to face" (12). ShashiDeshpande makes it clear through Urmi's mother, Inni, that mothers must be strong mentally and physically to take care of their children. The mother and the child must not give up the pleasure of being close with one another in life at any cost. Through these



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characters, ShashiDeshpande expresses that mothers must love their children and understand the value of children in life and contribute their best for them.

Children play a major role in taking care of their parents when parents are in need of support and care. Gabriel Garcia Marquez, a screen writer and journalist, reconnoiters: "Losing someone close to us in our lives is like losing a part of our body" (278). Similarly, Sumi finds herself to be an amputee. She carries the mixed emotions of despair and hope, and her unhappiness causes a host of symptoms of illness such as breathing difficulties, falling unconscious and so on. In these worse crises, it is her son, Kartik, who gives her moral support to live and helps her recover from illness. Kartik cannot stand the sight of his mother suffering and his love for his mother is obvious when he says: "Mama, you won't die, will you? She replies, 'No, Kartik, I won't die, I promise you, I won't die'" (TBV 19). Kartik loves his mother very much. Urmi sits close to Kartik with her head lying close and reckons: "I feel I've reached the limit of exhaustion, I must go to bed. But this breathlessness, the heaviness in my chest –is it only exhaustion? As I get up from Kartik's beside, I realize it's my asthma again. And this time no fear. I feel amazingly clear headed, all the confusion gone" (TBV150). Urmi gains this great hope and confidence through her son Kartik.

Rose Kennedy, a socialite and philanthropist of The United States of America, propounds: "It has been said time heals all wounds. I do not agree. The wounds remain. In time, the mind protecting its sanity covers them with scar tissue and the pain lessens, but it's never gone" (Philippines Daily). The scar left by her daughter's demise still remains in Urmi but her son consoles and heals her. Though the emptiness of life scares Urmi, she feels that she has to live for the sake of her son, Kartik. ShashiDeshpande's mother characters despite being whirled in the ocean of problems, never fail to be lovable and dutiful as mothers. Thus, ShashiDeshpande imparts to the readers that the crises faced are not barriers but they are strong stepping stones to nurture their relationship with their children..

REFERENCES

1. Deshpande, Shashi. *The Binding Vine*. New Delhi: Penguin, 1993.
2. Deshpande, Shashi. *Moving on*, New Delhi: Penguin, 2004.
3. Lombardi, Stone Kate. *The Mama's Boy Myth*. Penguin Group, 2012.
4. Dickinson, Emily. *Hope*. Harvard University Press, 1891, Lines 1-4.
5. Hasker, Tom. How Thomas Edison's mother was the making of him. Light House Global Community .<https://www.lighthousecommunity.global/post/how-thomas-edison-s-mother-was-the-making-of-him>. Accessed 11 June 2024.





Exploring the Prominence of Soft skills

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ABSTRACT

Soft skills otherwise called life skills are a group of skills which help individuals make implored choices, good understanding, and develop coping-up mechanisms. Individuals with these skills are highly friendly, able to work well with various kinds of people and skilled at assessing the emotions, motivations, desires and intentions of those around them. These skills also involve characters or conditions of a human being that aid to form his/her personality. Individuals who are strong in soft skills feel positive about what they are doing in their lives. They tend to enjoy self-reflection and analysis, explore relationships with others and assess their personal strengths.

Keywords: Soft skills, human condition, workplace behaviour, exploring and hard skills.

INTRODUCTION

The Oxford Advanced Learner's Dictionary defines soft skills as personal attributes that enable someone to interact effectively and harmoniously with other people. Soft skills are needed for everyday life in every place as much as they are needed in workplaces. Soft skills are the skills, abilities and traits that pertain to personality, attitude and behavior rather than to formal or technical knowledge. Soft skills may include an individual's ability for leadership, his or her oral and written communication, the willingness and aptitude for team-work, aptitude for conflict resolution and problem solving, the ability and willingness to learn, and the work ethics (Case 1998; Fann & Lewis 2001; Nelson et al. 2001; Taylor 2005a). Soft skills include one's ability to listen well, communicate effectively, approach positively, handle conflict, take responsibility, show respect, build trust, work well with others, manage time effectively, accept criticism, work under pressure, amiable to others and demonstrate good manners.

The importance given to imparting soft skills is spreading all over the world. Michigan State University, College of Agriculture and Natural Resource in association with the public and Land Grant Universities (APLU) and the



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University Industry Consortium (UIC) (2011) have studied the identification of important soft skills needed for successful transition from completion of baccalaureate degrees to competitive employment in agriculture (Pat Crawford et al. 2011). The researches related to teaching and training soft skills are gaining momentum in all disciplines of study across the world.

NEED FOR SOFT SKILLS

It is just not enough to be highly trained in technical skills, without developing the soft, interpersonal and relationship-building skills. Hence, soft skills must be acquired and practiced for successful living. Some common soft skills are perseverance, emotional maturity, effectiveness in professional life, adaptability, courage, verbal and non-verbal communication, positive attitude, mentoring and working well under pressure.

According to Dixon et al. (2010), soft skills are a combination of interpersonal and social skills that are considered as a complement to hard skills. Dixon et al. (2010) also say that researchers identify soft skills as predominantly behaviour-oriented and related to personal qualities and attitudinal proficiency (Rainsbury et al. 2002; Taylor, 2005b). Perreault (2004) defines soft skills as personal qualities, attributes, or the level of commitment of a person that set him or her apart from other individuals who may have similar skills and experience. On the other hand, Litecky et al. (2004) define soft skills as the cluster of personality traits, social graces [and] ...optimism that marks each one of us to varying degree. softskills.blogspot.com(2008) defines soft skills as personality traits, social grace, facility with language, personal habits, friendliness and optimism that mark people to varying degrees. Soft skills complement hard skills that are required for a successful career.

Soft skills are vital for all graduates regardless of their field of study. It is necessary for them to get acquainted with the behavioural skills of the work place as Stephen Johnston and Helen McGregor (2005) view. Modern professional practice requires not only the recognized technical skills, but also high-level of generic or soft professional skills. Recent professional laxity claims suggest that technically well-qualified professionals with deficiencies in these generic skills may fail to effectively identify and satisfy client requirements. Hard skills are those that are needed to perform a particular job. These often vary depending on the type of role that will be performed or the industry will be looking for. They can usually be developed through studying and training. Compared to soft skills, hard skills are normally easy to observe and evaluate because they involve specific skill sets related to the particular job of a worker (Pool & Sewell 2007). Hard skills are very much related to the technical procedures based on the core business of an organisation and they can be administrative.

Soft skills vary according to the nature of the workplace. Roselina (2009) discusses human capital development through the seven soft skill elements which comprise communication skills, critical thinking and problem solving skills, teamwork, lifelong learning and information, management skills, entrepreneurship skills, professional ethics and leadership skills.

The importance of soft skills is an undeniable fact in this age of information and knowledge. Soft skills are considered as a decisive factor for professionals throughout the world and its acquisition is vital for all the students at the tertiary level to get jobs at present. Good soft skills that help an individual to stand out in a milieu of routine job seekers with average skills and talent are in fact scarce in the highly competitive corporate world. Many employment experts strongly urge job seekers to enhance their soft skills along with their hard skills. Many employers are hesitant to hire technically skilled candidates who display little emotional intelligence in their career for they are unable to work well with others under stressful conditions. They want to select, retain and promote individuals who are dependable, resourceful, ethical and good communicators with willingness to work. Soft skills help in increasing these in the students' employability rate. For engineering and manufacturing sectors, as in any other type of jobs, the recruiters are keenly looking forward to soft skills in its potential employees besides technical skills. Possessing strong soft skills can put one a step ahead in the competition and make a true professional. CEOs and human resource managers are therefore ready to hire workers who demonstrate a high level of soft skills and then train them for the specific jobs available.





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The relationships between individuals and organisations are getting more and more complex. Having an excellent IQ and scoring high marks in subjects are not the criteria for success in professional or personal life. The ability to deal with one's feelings and understand the feelings of others in any given situation complements academic intelligence and cognitive capacity with a compassionate understanding of issues. This ability can be termed as soft skills.

SOFT SKILLS COMPLEMENT HARD SKILLS

Traditionally, hard skills have been regarded as the most essential element of academic success. Hard skills are academic skills, knowledge and one's level of expertise. But the recent researches suggest that hard skills contribute a mere 15% to one's skill success and the remaining 85% comprises soft skills. Hard skills are often associated with general intelligence throughout a students' academic history. The same cannot be assumed in the case of soft skills since they are flexible and can be developed through commitment and systematic practice.

Soft skills represent a fundamental attribute that today's knowledge based economy is demanding from its employers, employees and businesses. The nature of today's job demands creativity, confidence, assertiveness, perseverance and team building skills. As Luthans Fred (2002) states. No longer just dependent on financial capital or capital equipment, today's organizations need human capital (employees' experience, skills and creative ideas) to be used as leverage for competitive advantage.

The research conducted by Smyth Country Industry Council Workforce Demand Profile (2003) says . People most likely to be hired for available jobs have what employers call 'Soft Skills.' The council has given a list of personal traits and skills that employers state as most important when selecting employees for jobs of any type. They are flexibility, writing skills, basic spelling and grammar, posture, work ethic, adaptability, critical thinking skills, willingness to learn, good attitude etc.

It is also evident from several research studies that most of the job promotions happen because of the attitude of the employees and only a few because of their qualifications. The recent hiring strategy has completely changed when compared to the past. A survey conducted by the National Association of Colleges and Employers (NACE 2008) reports, The top characteristics looked for in new hires by 276 employer respondents have been soft skills, communication ability, a strong work ethic, initiative, interpersonal skills and teamwork. Acquiring soft skills has been acknowledged as important amidst the stiff competition for jobs in the industry today and the large number of graduates produced locally and abroad (Abang Abdullah 2005). In today's ever- competitive job market, the measure of an individual's general career success is the ability to use these soft skills to adapt to any assignment.

CONCLUSION

Though students at the tertiary level possess certain people skills due to their background and exposure, they are inadequate to impress the recruiters. The corporate sectors seek and opt for candidates who not only have the requisite academic qualifications but also soft skills to function in the competitive corporate setting where they have to deal with people of different culture. So, training in soft skills has become compulsory for today's graduates. Universities and colleges all over the world adopt many training techniques considering the industrial scenario and to cater to the needs of students. Training in soft skills is one such indispensable part of academics that helps students become dynamic in their career.

REFERENCES

1. Abang Abdullah, AA 2005, 'Teacher of engineering and graduate employment : A professional perspective', Proceedings of the Regional Conference on Engineering Education, Johor, Malaysia, pp. 12-13.
2. Case, TL 1998, 'Using training ads to identify high demand IS / IT job skills and competencies', ERIC Database ED 431418.





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3. Dixon, J, Belnap, C, Albrecht, C & Lee, K 2010, 'The importance of soft skills', Corporate Finance Review, vol. 14, no. 6, pp. 35 -38.
4. Helen Mcgregor 2005, 'Soft skills are hard', Asia Pacific Journal of Cooperative Education Recognizing and Supporting a Scholarship of Practice.
5. Litecky Chuck Kirk, P, Arneet & Prabhakar Bipin 2004, 'The paradox of soft skills versus technical skills in IS hiring', Journal of Computer Information System, Fall.
6. Luthans Fred 2008, 'Organisational behaviour', McGraw Hill Education, Asia.
7. Nelson, WA, Wellings, P, Palumbo, D & Gupton, C 2001, 'Combining technology and narrative in a learning environment for workplace training', ERIC Database ED453807
8. Pat Crawford, Lang, S, Fink, W, Dalton, R & Fielitz, L 2001, 'Comparative analysis of soft skills: what is important for new graduates?', Washington, DC, Association of Public and Lang-grant Universities.
9. Perreault, H 2004, 'Business educators can take a leadership role in character education', Business Education Forum, vol. 59, no. 1, pp. 23-24.
10. Rainsbury, E, Hodges, D, Burchell, N & Lay, N 2002, 'Ranking workplace competencies: Student and graduate perceptions', Asia Pacific Journal of Cooperative Education, vol. 3, no. 2, pp. 8-18.
11. Roselina Shakir 2009, 'Soft skills at the Malysian institutes of higher learning', Asia Pacific Educational Review, vol.10, pp. 309-315.
12. Taylor, A 2005, 'What employers look for: The skills debate and the fit with youth perception', Journal of Education and Work, vol. 18, no. 2, pp. 201-218.





Tilling the Earth, Telling the Tale: Ecological Layers in John Steinbeck's, *The Grapes of Wrath*.

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ABSTRACT

Natural calamities are inevitable. Sustainability plays a vital role in this research article titled, Tilling the Earth, Telling the Tale: Ecological Layers in John Steinbeck's, 'The Grapes of Wrath.' The research article deals with the historical calamity that plundered the natural habitat of the Southern parts of North America. The Dust Bowl was the result of severe dust storms that annihilated the ecology and agriculture of the American society in the 1930's. John Steinbeck, the 19th century writer gave his readers an outline sketch of the difficulties faced by the people during the dust storm and its after effects like migration and capital exploitation. Through a green lens, the research article is explored based on the ecological layers present in the novel "The Grapes of Wrath" and how ecological reflex play a tragic role on human beings sustainability. In this study the writer analysed the novel, *The Grapes of Wrath* written by John Steinbeck by using certain Eco critical approaches proposed by Peter Barry, in his book 'The Beginning Theory.' The ecological layers present in the novel delineates nature as both a provider as well as a destroyer. The reminiscence of human beings about their relationship with their natural environment adds an emotional scintilla to substantiate the concept that nature and human beings are inseparable.

Keywords: Ecology, Dust Bowl, Sustenance, Coalescence, Vulnerability, Socio-environmental concerns.

INTRODUCTION

The twentieth century's American literature is notable because its writers strove to portray everyday life as an authentic one. Fiction showed the new social and economic conflicts and imbalances that arose from the fast industrialization and dissolution of the farmers realistically. As Ralph Waldo Emerson quoted, "America is a poem in



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our eyes: its ample geography dazzles the imagination, and it will not wait long for metres” (qtd. in Richard Gray 1). Studying John Steinbeck’s works is crucial because the psychological and physical hardships his characters faced mirror the nation’s political, social, and economic shifts. Through his works, he delves into the socio-environmental shifts and mass conflicts that brought home to Americans the significance of liberty, sustainability, and unity.

In his novel, *The Grapes of Wrath*, John Steinbeck skilfully captured the family’s uprightness and dignity in the face of adversity, challenges and powerful, impersonal commercial impulses. Based on his visits to labour camps, where he saw the appalling living circumstances of immigrant families, he created his remarkable masterpiece. Because of its amiable, informal manner, working-class readers loved and applauded his novel, while corporate and government officials found it offensive and slanderous, labelling it as “communist propaganda.” Despite this, it was the best-selling book of 1939, and in 1940, it was awarded the Pulitzer Prize. The same year, John Ford’s well regarded film adaptation of this novel was released.

The research article is written in regards to the events that delve into a noteworthy period of American history, portraying the struggles faced by millions of people whose lives were destroyed by the Dust Bowl and the Great Depression. The proposed study is to concentrate on the country’s perception of and empathy for human hardships. The chosen work depicts the migration of families that spurred on by unfavourable atmospheric conditions, excavation of land and riverbeds, and the bankers’ exploitation of the farmers who have been dispossessed of their lands, which results in poverty, immoral lifestyles, and unemployment. Though the disposition of the land is unforeseeable, still it envisage the people who lived and moved by creating an inevitable bond between them and the land. In an intercalary chapter in the novel, *The Grapes of Wrath*, a tenant farmer who is evicting his family from their homeland explains to the tractor driver about the special bond between man and land:

If a man owns a little property, that property is him, it’s part of him, and it’s like him. If he owns property only so he can walk on it and handle it and be sad when it isn’t doing well, and feel fine when the rain falls on it, that property is him, and some way he’s bigger because he owns it. Even if he isn’t successful he’s big with his property. That is so. (48)

The coalescence between man and natural habitat in Steinbeck’s, *The Grapes of Wrath*, has led to an analysis of his work through ecocritical perspective. Cheryl Glotfelty is the acknowledged founder of Ecocritics in the United States of America. As a pioneer in this field she says as follows:

Simply put, ecocriticism is the study of the relationship between literature and the physical environment. Just as feminist criticism examines language and literature from a gender conscious perspective, and Marxist criticism brings an awareness of modes of production and economic class to its reading of texts, ecocriticism takes an earth-centred approach to literary studies. (Introduction xviii)

Ecocritical concerns are present in Steinbeck’s writings to a large extent. His extraordinary enthusiasm for biology, preservation and the general interrelatedness of all forms of life has moulded his speciality in this field. His speciality has in turn moulded the American’s creative energy and has persuaded his followers to have an ethical outlook towards the regular world. The four shades of ecocriticism are analysed by the researcher and the major focus is on the landscape, one of the attributes of nature which has prominence in Steinbeck’s select novels. The article examines Steinbeck’s affinity to nature as well as the destructive power of his native land.

As stated in Peter Barry’s book, *Beginning Theory: An Introduction to Literary and Cultural Theory* (2002), there are four shades of nature in ecocriticism. This acts as a base to understand to which type, Steinbeck’s novels belong to. The first section addresses the wilderness, which includes the oceans, deserts, and uninhabited continent. The second area deals with the scenic sublimines like the forests, lakes, mountains, cliffs and waterfalls. In the third region, that is,



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the countryside, the features that pertain to the woods, fields, and hills are discussed. The final region recognized as Parks, gardens, and lanes are features of the domestic picturesque. The second and third areas—the scenic sublime and the countryside—can be used to analyse some of Steinbeck's *The Grapes of Wrath*. When Steinbeck describes his homeland with vibrancy, there are hints of woodlands, fields, mountains, cliffs, waterfalls, hills, and sceneries. Meinig describes the relationship between the natural and cultural landscape as:

Nature is fundamental only in a simple literal sense; nature provides a stage. The earth is a platform, but all thereon is furnished with man's effects so extensively that you cannot find a scrap of pristine nature. The soils, trees, and streams are not —nature as distinct from man, they are profoundly human creations. (36)

Steinbeck has presented both natural and cultural landscapes on numerous occasions in *The Grapes of Wrath*.

He uses these panoramas as a serene backdrop or setting for his novel. Steinbeck could have drawn inspiration for these landscapes from regions he knew well. According to Denis Cosgrove, "Landscape denotes the external world mediated through subjective human experience... Landscape is not merely the world we see; it is a construction, a composition of that world. Landscape is a way of seeing the world" (13).

In this article the researcher has discussed the tremendous changes that took place in greater parts of the landscapes of the Southern Plains due to the Dust Bowl. The once considered as a provider has now become a destroyer. People were left to endure a new trauma that led to the mass migration in history. Bloom explains the dust storm as follows:

In the south-western Great Plains, the land had once been covered with grasses that held the soil in place through both drought and flood, but when the farmers ploughed the grass to grow wheat and raise cattle, they left the earth exposed. When the drought hit the region, the soil began to simply blow away; at times, the wind picked up so much soil that the sky turned dark, and the wind-born dust was reported to have travelled as far as the Atlantic ocean.(4)

Life has always been difficult for the Joads as they always underwent various turmoil throughout the novel.

The vision and hope of having a better life in California was undetermined. The picturesque view of Dust Bowl and its after-effects determines the lifestyle of the Joad family. According to the German geographer, Friedrich Rätzl Environmental Determinism plays a significant role in determining the environment according to human behaviour. It posits that the physical environment, particularly the climate and terrain that actively shapes cultures, societies, and human behaviours.

In *The Grapes of Wrath*, the Dust Bowl's severe environmental conditions directly influence the lives of the tenant farmers, forcing them to migrate in search of better opportunities. The novel begins with vivid descriptions of the parched and desolate land which establishes the harsh environmental context that compels the Joad family to leave their homeland. The environmental degradation, driven by both natural drought and poor agricultural practices, underscores the idea that the land's condition dictates human movement and socio-economic outcomes.

In the very beginning of the novel, *The Grapes of Wrath*, the Oklahoma nation has been described as the land somewhat secured with red soil and halfway with dim soil. It has been raining for a couple of days, which made the corn crops lift. The weeds are scattered among the grass and in addition, on the streets, the rain helps in covering the entire red and dark land with green fields. Before the end of the month of May, in the novel, the sky becomes pale and the mist which is clear and brilliant begins to scatter. Soon the harvest begins to decay and because of the warmth of the sun even the mist begins to vanish. The weeds which are spread among the grass begin to droop, prompting an untold dry season.





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Steinbeck's depiction with respect to the drying of the yields is clarified by description of how the sun's warmth twist the stems of the produce and make the leaves droop from their solid erect position at last bringing them down pitifully. This shows the beginning of the ecological malfunction that will turn upside down the normal lifestyle of the people of Oklahoma. The warmth of the sun heats the place savagely for an endless amount of time and the entire vegetation crumbles. Lastly both the sun and the land blur. "The weed frayed and edged back towards their foundations. The air is thin and the sky is more pale and regular; the earth withered" (4). The extreme breeze of the sand makes it troublesome for the people's lifestyle. Due to that, the general population suffers from enormous smokes of dust at every point when the haggles' steeds move. There is sand everywhere which mounts up to the wall and even to the abdomen of men. It takes many days to pick up the original self.

Toward the end of the long stretch of June the nation begins to recapture its typical state, where the ranchers in the field have a feeling of expectation when they see the dribbles of water pit on the land and additionally on the corns. Steinbeck has plainly outlined this occasion as follows: "The men in the fields gazed toward the mists and sniffed at them and held wet fingers up to detect the breeze... The rain-heads dropped a bit of splashing and rushed on to some other Nation" (4). However, sadly, the rain mists were driven northward by the delicate breeze and as days went the breeze all of a sudden spouted in seriousness.

The dust at that point devoured every part of the land once again. This extreme natural change affected the general population's livelihood. The dust developed dim tufts like smoke which was noticeable all around. There was a dry hurried sound made by the breeze among the yields. It wiped out even the little hunks on the fields. The intensity of the breeze was heavy during the night. The air and the sky were obscured and among them the sun shone red with a crude sting that choked the general population not to be able to breathe. This crude breeze which was over-whelming incapacitated the rooflets and made them to settle sideways pointing the side of the blowing wind. The following day there was no daylight. The sun showed up in a red edge drifted with a gentle light and inside a couple of minutes, again the sky obscured and the breeze howled among the yields.

Within the evening, even the stars could not break into the sky and because of the dust, the window lights could not give enough light to the yards. The dust devoured the entire place. The houses were closed and even the little openings were wedged with garments. Still the dust burst in so daintily like the dust grains. There was dust all over the place. They were seen on the tables, seats and even on the dishes. Consistently the breeze passed on like a trickster and left the territory tranquil and still.

The general population, who settled in their homes, heard these heavy winds even while lying on their beds to rest at night. Owing to the stink that is due to the severe dust, individuals laid back in their homes. They wrapped their noses with cloths and safeguarded their eyes with goggles. All they needed was an ordinary life, that is, the existence they had before the dust storm. It was hard for them to survive the spouting breeze. As there was no daylight, they longed for mornings to come. There were hot sand torrential slides all over the place. Once the dust filtered from the sky, people began to leave their homes.

As they could feel the hot sting of the sun, they wrapped themselves with fine garments to safeguard them of the consuming sun. Kids did not play as usual and men looked over their walls and saw their destroyed harvests with bewilderment. Women went with their men in order to help them in whatever choice they were about to make regarding their destroyed harvest. They felt that their men had some sort of hope even in their edgy condition. The kids too felt confused of their elders' response. Yet, unexpectedly, the heart broken men lost their dazed perplexity and turned out to be hard and furious. Soon the women begin to comprehend that, if their men worked united, things could soon be set right. With this inspiration the ladies went into their homes to do their daily chores and the children started to play. Indeed, even the sun turned out to be less red and the men began to plan their future undertakings while sitting in their doorway.





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This profound portrayal of the dust storm goes about as the foundation cause which influences a large number of local individuals to move from their home state to their neighbouring states looking for occupation and a better living. The destructive and the uncertain nature of the climate as well as the selfish materialistic minds of the human beings afflicts the people and makes them realise that their land is corrupted and made unfit for further cultivation and also to lead a normal life. Therefore the people are compelled to leave their native land in search of a better living. Uncertainty and disappointments play a vital role in the peoples' life as they travel to a destined country with a hope of better living condition. In moving from Oklahoma to California's magnificent brutal forces by value driving landowners and agri-business entrepreneurs, the refuge fruit pickers find only disappointments and losses. Everett Lee explains this unexpected situation as follows:

Knowledge of the area of destination is seldom exact, and indeed some of the advantages and disadvantages of an area can only be perceived by living there. Thus there is always an element of ignorance or even mystery about the area of destination, and there must always be some uncertainty with regard to the reception of a migrant in a new area. (50-51)

This research article helps in portraying the coalescence of man and nature. Human beings lives are destined upon the way he treats nature and the environment in which he lives and move. Human beings cannot escape the wrath of nature if they continue to annihilate and afflict the environment in which they depend upon. The Dust Bowl acts as nature's wrath upon man's doings and the aftermath is regarded as human beings' fate. The only way to resolve these impacts is to create a better living condition for man by creating a bond and a sense of responsibility towards nature and environment.

REFERENCES

1. Bloom, Harold. Bloom's Biocritiques: John Steinbeck. Chelsea House, 2003.
2. Cosgrove, Denis E. Social Formation and Symbolic Landscape. Croom Helm, 1984.
3. Gray, Richard. A Brief History of American Literature. Wiley-Blackwell, 2011.
4. Glotfelty, Cheryll. —Introduction: The Ecocriticism Reader: Landmarks in Literary Ecology, edited by Cheryll Glotfelty and Harold Fromm, University of Georgia Press, 1996, pp. xvi-xviii.
5. Lee, Everett S. —A Theory of Migration: *Demography*, vol. 3, no.1, 1966, pp. 47-57.
6. Steinbeck, John. The Grapes of Wrath. Penguin Books, 1964.
7. Meinig, D. W. —The Beholding Eye: Ten Versions of the Same Scene. || The Interpretation of Ordinary Landscape: Geographical Essays, edited by D. W. Meinig, and John Brinckeroff Jackson, Oxford University Press, 1979, pp. 33-48.





Coping Mechanism: A Psychological Approach to Rohinton Mistry's Works

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ABSTRACT

Lazarus and Folkman's (1984) coping mechanism theory is significant in contemporary literature and remains the keystone of psychological stress and coping in literary works. Coping is, managing internal and external traumatic situations in life. Literature provides us an opportunity to peep into different trajectories of life even without experiencing them. Rohinton Mistry Indian-Canadian writer uses this power of literature to make humans understand the complexities of life and infuse them with hope to continue life amidst all social injustices, political bias and familial mess. This paper analyses the coping Mechanism theory based on the justification that Mistry's characters reconsider, rebuild their life and change the dreams and expectations of life when they have to negotiate physical, emotional, mental imbalances on account of personal, social, and political issues. In addition, his characters have the distinctive ability and unflinching capacity to fight against the existential and catastrophic threats for survival.

Keywords: Coping mechanism, Psychological Approach, Social injustices, Political bias, Catastrophic threats.

INTRODUCTION

Rohinton Mistry's books portray multiple facets of Indian socioeconomic life; as well as Parsi Zoroastrian life, traditions, customs, and religion. *Tales from Firozsha Baag* (1987) is a collection of eleven interconnected stories that explore the lives of several residents in a Bombay apartment complex. Mistry particularly focuses on the Parsi





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community, a small religious minority that traces its roots to Zoroastrianism and ancient Persia, in this volume. By examining the Parsi culture through a combination of sympathy and criticism, Mistry analyzes the conflicts that arise among Parsi individuals both in Indian society, where they are often excluded by the predominant Hindu and Muslim populations, and in Western nations. Several characters in the collection reject Parsi tradition and embrace secular, more modern customs, as in "The Exercisers" and "The Condolence Visit". Others struggle to maintain their faith in light of religious doubt and other formidable challenges. In stories such as "Auspicious Occasions", women are downgraded to subordinate roles in relationships and are forced to sacrifice their own independence and dreams in favor of societal concurrence and harmonious familial relationships.

Alienation is another thematic concern in the stories, particularly in those that focus on the diasporic experience. As Kersi, the protagonist in "The Swimming Lessons", has trouble adjusting to his new life in Canada, he feels dislocated from his Indian heritage as well as from the modern Canadian culture around him. In "Lend Me Your Light", the protagonist feels guilt for leaving his family and his homeland after moving to Toronto. As a small religious minority, the residents of the housing complex often experience conflict with Indian society, where they are often excluded by the predominant Hindu and Muslim populations. The first set of stories in *Tales From Firozsha Baag* (1987) "Auspicious Occasion", "One Sunday", "The Ghost of Firozsha Baag", "Condolence Visit", "The Collector", "Of White Hairs and Cricket", "The Paying Guests", and "Exercisers" exaggerate the conflict between the traditional Zoroastrian life and modernity which is the outcome of westernisation. These eight tales also focus on the adaptability of the Parsi community to the various levels of westernisation. In another set of stories, namely "Squatter", "Lend Me Your Light" and "Swimming Lessons", Mistry deals with the impact of expatriation on the lives of young Parsi protagonists abroad. The collection of stories depicts the emotional and cultural conflicts in the minds of the characters. Mistry focuses on the internal conflicts of the characters which may be the result of cultural, spiritual and psychological crises undergone by the characters. L. A. Gottschalk says, "displacements and denials in mentally healthy individuals are more likely to function as coping mechanisms" (237–260).

Rohinton Mistry's first novel *Such a Long Journey* takes place in 1971, Bombay against the backdrop of war in the Indian subcontinent, and the independence of Bangladesh. This novel shows the anguish of middle-class Parsi Gustad Noble who works in a bank as a clerk. Gustad, the lover of God, leads his life with honesty and gentleness. With his three children and his wife Dilnavaz he lives in Parsi Residential colony of Khadabad building, Bombay. As a father he wants to give an advanced education to his eldest son Sohrab to avoid troubles in future but his son has his own preference which creates a rift between the father and the son. It shatters the hopes of Gustad. Mistry brings out the political injustices through Gustad's friend Major Jimmy Bilimoria who dies at the end by the brutality of the authorities.

Susan Folkman, and Judith Tedlie Moskowitz say, "Coping, defined as the thoughts and behaviors used to manage the internal and external demands of situations that are appraised as stressful, has been a focus of research in the social sciences for more than three decades" (745-774). *A Fine Balance* (1995) is a story of four main characters whose lives come together during a time of political turmoil after the State of Internal Emergency in India. Through the days of desolation and expectation, they become inextricably intertwined with their circumstances. Mistry shows the adventures of downtrodden people as they drift from place to place and from one social environment to another for their survival. In one of his interviews he comments that life itself is a journey and one starts shifting his place from his time of birth. Mistry shows that during the period of Emergency in India the fundamental rights of the people were declined, the press was censored, with the new law MISA anybody could be imprisoned without trial.

Mistry brings to light that there were countless deaths in police custody. Mistry boldly attacks on the political injustices and the insensitivity of the ruling classes. During elections, the illiterate villagers are cheated and the ballot papers are filled by men hired by the politicians. Mistry displays the struggles of various characters with varied situations and events through this novel. *Family Matters* is a story of a middle class Parsi family in Bombay during the post Babri Masjid demolition period in nineteen nineties. *Family Matters* depicts many issues such as old age, familial bondage, human relationship, cosmopolitan city life, secularism, corruption, gambling, communalism,





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suffering, death, immigration, alienation and sense of belongingness etc. The middle class family faces pressures to take care of an aged and infirm patriarch in this novel. This story offers a consideration of how, despite all efforts to keep the characters separate, the public world interrupts the private space, and how greed can corrupt even the most upright persons of communities. Mistry's major focus is on subaltern characters that are capable of vanquishing their hurdles at various stages. In all his writings the characters possess exceptional resilience through which they surf through the winds and storms of life. Mistry through his writing skills transport his readers to a world which they have not seen and make them feel as if they too have undergone the similar experiences.

The novels *Such a Long Journey* (1991) and *Family Matters* (2002) are taken for analysis. *Such a Long Journey* (1991) exposes the lifestyle of a common man and concerns of the Parsi community during post-Independent India. This novel investigates the social, political, and cultural chaos during the early sixties and seventies. Mistry brings out the major political issues like corruption, domination, and unlawful government without hesitation or fear. Mistry's writing shows the realistic conditions of commonman and political history of the Indian society. The protagonist of the novel Gustad maintains dignity, strong mind, and humanity during the storms of life. He endures frustration, confusion, disloyalty and corruption and his endurance makes the readers feel the height of perseverance. He is dedicated to his family, and he works hard to uphold his family's financial condition. As a Noble father of three children and faithful friend to Major Jimmy Bilimoria and Dinshawji he fulfils his duty very ardently. Mistry shows the struggle of the Parsi community during the period of Indira Gandhi. The Parsi community feels that they will become "second-class citizens" of India in the future as they are a marginalized minority community. Mistry pictures Parsis' sense of displacement in this novel through Gustad Noble who tries to cope with multi-layered difficulties in his life. Compas, B. E., says, "Healthy coping strategies, such as relaxation, seeking support from our loved ones, and positive reframing of unhelpful cognitions, are designed to foster resilience" (2001).

Family Matters portrays the struggles of man at the end of his life. Nariman is angry at the predicament of old age, at his alienation from his family and at the world that no longer understands him. He fulminates in ways that are poignant and soul stirring. The novel mirrors the disjointed thoughts of an elderly man as he struggles with the day to day process of ageing, mistreatment at the hands of his family and the viciousness inflicted in the world around him. The novel hints out one's own duty towards their loved ones. Mistry brilliantly transports the readers to the ages that they do not belong with his in depth brilliant narration. Mistry's works make one feel like sneaking into an unknown person's life with such an intensity of feeling that one starts growing a bond with his characters and starts feeling and reacting to what the characters are confronting. According to Thoits, "social support and access to resources play crucial roles in shaping our individual coping strategies" (1995).

The novels *Such a Long Journey* (1991) *A Fine Balance* (1996) are taken for analysis. In *Such a Long Journey* as a noble father of three children and a faithful friend to Major Jimmy Billimoria and Dinshawji the protagonist Gustad Noble fulfils his duty very ardently. Mistry clearly brings out the internal and external conflict that the people of the Parsi community underwent during the period of Indira Gandhi. The Parsi community feels that they would become "second-class citizens" of India in the future as they are a marginalized minority community. Mistry pictures Parsis' sense of displacement in this novel through Gustad Noble who tries to cope with multi-layered difficulties in his life. In the novel *A Fine Balance* Mistry exposes India's socio-cultural aspects of caste system, poverty, inequity and exploitation of a common man. Mistry's characters battle against the cruel system of brutality, injustice, and discrimination to balance their life. Like Dorris Lessing who aspires for "A unity in the world system" (qtd in Mukhopadhyay xii) in her novel *The Golden Notebook* Mistry tries to bring humanity into the hearts of people who have power in their hands. *A Fine Balance* deals with human efforts for dignity and their continuous struggle to sustain a balance between desire for dignified survival by fighting discrimination and humiliation of an aggressive milieu. Om Prakash and Ishvar want to escape from the oppressive caste system in their village and they seek a shelter in the city, Bombay. They experience various kinds of trauma in the city by authoritative politicians. They swim against the waves in the modern city Bombay. They make their mind strong to balance the troubles in life. They choose the next step to come out of the problem to lead their life in a dignified way. Mistry introduces the young man, Maneck Kolah, a Parsi, who





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represents youthful countenance of modern India. Maneck is forced to move from his homeland in the hills to the modern city Bombay for his education. Mistry brings out the theme of nepotism, corruption, and government interference in educational institutions which destroy the dreams and desire for excellence of the students. Maneck's friend Avinash helps him to understand the worst education system in India. Maneck is not able to fight against the system and chooses his next option to leave abroad and returns in eight years to India. Maneck is not able to find a comfort zone in his life and he feels spiritless to raise his soul and completing his life by attempting suicide. Mistry conveys a message through the negative character Maneck that life starts with struggle and people must face the obstacles in life and not be fed up by the tribulations. Beck says, "The reinforcement of pessimistic thoughts and negative assumptions about ourselves can perpetuate and magnify our distress" (2019).

Coppens CM, de Boer SF, Koolhaas JM. say, "Proactive individuals excel in stable environments because they are more routinized, rigid, and are less reactive to stressors, while reactive individuals perform better in a more variable environment" (4021-8). Dina Dalal, Parsi woman is a widow at the age of twenty two wants to lead an independent life after her husband's death. Her life starts from her brother's house where she faces emotional suppression of the patriarchal system. She is an independent woman who desires to educate herself, financially independent and marry a man of her own choice. After her husband's death she determines to begin her life anew. She starts tailoring for an export company with the help of Om Prakash, Ishvar and her paying guest Maneck. As a forty years old woman has weakened her eyesight, she has to struggle to balance her life. Dina Dalal keeps her spirit strong to balance herself emotionally and physically. Mistry's characters raise their strength of mind to reiterate the human spirit to battle in life. According to Seligman and Csikszentmihalyi "Avoidance and denial involve ignoring or suppressing distressing emotions or situations" (2014).

Firozsha Baag is a residential block for the middle class Parsi inhabitants, in Bombay. Mistry brings the conflict between traditional religion Parsi and personal flexibility creates tension in each story. Older Parsis fear the violation of the changing world of their community by the younger generation. Parsis in Firozsha Baag are middle class in Bombay who engage in daily battle with irregular water supply, peeling paint of old homes, and falling plaster. Mistry focuses on superstitious belief and Parsi community ritual death for funeral rites in his stories. Mistry brings the status of Parsis in postcolonial India where they were downgraded. The economic condition and communalist philosophy make them feel despair and disillusionment and change the route out of India to Western countries. They experience western culture and attempt to adapt themselves for the environment but struggle for cultural heritage. They undergo mental agony and return to their homeland India. They enlighten by their experiences in western culture. According to Algorani and Gupta, Coping consists of our "thoughts and behaviors mobilized to manage internal and external stressful situations" (2021, p. 1).

Mistry states that the postcolonial immigrant forces to come to terms with the dualities and hybridity. Coping skills usually help in adjusting to or tolerating changes in life to maintain a sense of worth and emotional balance. Human beings are not in control of life and coping mechanisms help them in the process of adaptation. The characters of Mistry follow coping strategies in order to stand against the torment both physical and mental. They continuously battle for balance when life throws them to unexpected and tough situations. Their bitter experiences teach them how to turn their mess into a message and thereby attain enlightenment.

The characters use several of the coping strategies whenever they confront existential threats. They lower their expectations; they ask help from others without hesitation, they take responsibility for their circumstances, they maintain the emotionally supportive relationships they revisit and question the previously held beliefs that are no longer worthy to follow. Some characters view their problems with a religious lens. They use different strategies and successfully cope up with the demands of different situations. Mistry's works confirm the theme of endurance with regard to the selected works of Rohinton Mistry. An attempt is also made to reveal the agonies, sufferings and excruciation of the poor and downtrodden people because of stereotypes, prejudice and discrimination. Rohinton Mistry deals with the Parsi community issues; he brings out the common societal evils prevailing in every nation to light. The relationship between the individual and the society plays a vital role in the working of every individual's



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mind. Humans are influenced and shaped by the society and the environment that they live in. Every individual is expected to handle the demands and the forced limitations or restrictions of the society and culture. The response or the reaction by an individual is more important in certain circumstances or events. Endurance is the much needed one to achieve the goals and aspirations of life no matter physical or mental health. According to McCrae, R. R. (1984). "A number of mechanisms under conditions of challenge, including rational action, perseverance, positive thinking, intellectual denial, restraint, self-adaptation, drawing strength from adversity, and humor" (919–928).

Mistry's characters help readers to developmental toughness amidst the inability or helplessness. Though society prevents them from continuing the march towards certain dreams it cannot stop them from changing their dreams. They accept changes during crisis, choice or chance. They bury the regrets of their past and focus on building a new life by reconsidering their life and circumstances. Folk man and Moskowitz say, "Coping is an essential psychological process for managing stress and our emotions" (2004). Thus, Mistry carves his characters in such a way that despite the difficulties and challenges they land themselves safely and leave their power of endurance as their legacy.

REFERENCES

1. Algorani, E. B., & Gupta, V. (2021). Coping mechanisms. StatPearls. <https://www.ncbi.nlm.nih.gov/books/NBK559031/>.
2. Beck, A. T. (2019). Cognitive therapy of depression. Guilford Press.
3. Compas, B. E., Connor-Smith, J. K., Saltzman, H., Thomsen, A. H., & Wadsworth, M. E. (2001). Coping with stress during childhood and adolescence: Problems, progress, and potential in theory and research. *Psychological Bulletin*, 127(1), 87–127.
4. Coppens CM, de Boer SF, Koolhaas JM. Coping styles and behavioural flexibility: towards underlying mechanisms. *Philos Trans R Soc Lond B Biol Sci*. 2010 Dec 27;365(1560):4021-8.
5. Folkman, S., & Moskowitz, J. T. (2004). Coping: Pitfalls and promise. *The Annual Review of Psychology*, 55, 745–774.
6. Gottschalk, L. A., Fronczek, J., & Abel, L. (1993). Emotions, defenses, coping mechanisms, and symptoms. *Psychoanalytic Psychology*, 10(2), 237–260. <https://doi.org/10.1037/h0079459>
7. McCrae, R. R. (1984). Situational determinants of coping responses: Loss, threat, and challenge. *Journal of Personality and Social Psychology*, 46(4), 919–928. <https://doi.org/10.1037/0022-3514.46.4.919>
8. Seligman, M. E. P., & Csikszentmihalyi, M. (2014). *Positive psychology: An introduction*. In M. Csikszentmihalyi, Flow and the foundations of positive psychology (pp. 279–298). Springer.
9. Susan Folkman, and Judith Tedlie Moskowitz (2003). A Review in Advance Vol. 55:745-774. 3 February 2004 <https://doi.org/10.1146/annurev.psych.55.090902.141456>
10. Thoits, P. A. (1995). Stress, coping, and social support processes: Where are we? What next? *Journal of Health and Social Behavior*, 35, 53–79.





The Enduring Significance of Literature in the Digital Age: A Comprehensive Exploration

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ABSTRACT

Literature, an ever-evolving facet of human culture, continues to play a pivotal role in contemporary society, offering a rich reservoir of emotions and experiences. Despite the relentless march of progress, literature retains its significance as a source of entertainment, enlightenment, and empathy. In an age dominated by digital media and rapid technological advancements, the significance of literature in shaping human consciousness and societal norms has become increasingly pronounced. This article delves into the multifaceted importance of literature in contemporary society, drawing upon diverse examples and insights from literary luminaries to underscore its enduring relevance in the digital age. Through meticulous analysis, it aims to elucidate literature's profound impact on human consciousness, societal norms, and cultural identity. Through an in-depth analysis of key themes and seminal works, this paper explores the profound impact of literature on human consciousness, societal norms, and cultural identity while also exploring its evolving role in navigating the complexities of the digital age.

Keywords: Literature, Contemporary society, Empathy, Critical Discourse, Cultural identity, Human consciousness, Digital age, Self-reflection, Collective memory, Cultural heritage, Digital Consumption and Cultural Materialism.



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INTRODUCTION

Literature, from the ageless prose of Charles Dickens to the transcendent verse of William Wordsworth, has long been used as a social mirror, capturing the joys, sorrows, and complexity of the human condition. The classic quotation from Charles Bukowski, "Without literature, life is hell," captures the transformational potential of literature. This introduction lays the groundwork for an examination of literature's continuing relevance in current society. It does this by fusing the perspectives of literary greats with modern academics to highlight the many ways that literature shapes both societal standards and individual viewpoints.

Literature as a Reflection of Human Experience

Literature is fundamentally a storehouse of human experience, encapsulating the rainbow of feelings, hardships, and victories that make up our lives. Literature offers a glimpse into the human psyche, from the epic tales of Homer's *Odyssey* to the moving sonnets of Elizabeth Barrett Browning. C.S. Lewis noted astutely that "Literature adds to reality, it does not simply describe it," emphasizing the capacity of creative imagination to transform. We explore how literature replicates societal ideals, cultural conventions, and individual psyches, providing important insights into the human condition through an analysis of influential works spanning numerous genres and historical epochs. Furthermore, literature has the reflecting ability to shape reality in addition to merely recording it. "Word after word after word is power," as Margaret Atwood once said. Literature can even spark social change by influencing readers' perceptions through tales and character development. Books like Harper Lee's *To Kill a Mockingbird* and George Orwell's *1984* have not only reflected societal challenges but also generated important discussions and efforts toward justice and equity.

The Role of Literature in Fostering Empathy and Understanding

The power of literature to promote empathy and understanding among people beyond time, place, and circumstance is one of its most enduring legacies. Literature allows readers to experience the lives of individuals that are very different from their own, from the existential sorrow of Albert Camus' *The Stranger* to the moral complexity of Leo Tolstoy's *Anna Karenina*. *To Kill a Mockingbird* by Harper Lee eloquently states, "You never really understand a person until you consider things from his point of view... until you climb into his skin and walk around in it." We shed light on how literature fosters empathy, compassion, and cross-cultural understanding, enhancing the richness of the human experience via an examination of a variety of literary works. Moreover, research from science confirms the literature's contribution to empathy. Reading fiction regularly improves one's ability to comprehend the feelings and perspectives of others, according to research by Raymond Mar and colleagues. In our increasingly globalized world, empathy—which is fostered by literary engagement—is crucial for creating more peaceful and cooperative communities.

Literature as a Catalyst for Critical Discourse

Literature encourages critical discourse, which challenges prevalent beliefs and challenges readers to question accepted conventions, in addition to its role in building empathy. Literature has long been used as a tool for dissent and social change, from the feminist critiques of Virginia Woolf's *A Room of One's Own* to the stinging social satire of George Orwell's *Animal Farm*. According to Salman Rushdie, "Literature is the one place in any society where, within the secrecy of our heads, we can hear voices talking about everything in every possible way." We demonstrate how literature may elicit reflection, foster discussion, and motivate group action by analyzing literary works that tackle urgent social challenges. The ability of literature to provoke and question is not just ancient but also current. This tradition is carried on by modern writers like Chimamanda Ngozi Adichie and Ta-Nehisi Coates, who tackle racial, gender, and power-related issues while challenging readers to face hard realities and push for change. James Baldwin once said, "Not everything that is faced can be changed, but nothing can be changed until it is faced."

The Evolution of Literature in the Digital Age

The emergence of digital technologies in the twenty-first century has caused a significant shift in literature. Literature has embraced new distribution channels, such as e-books and internet platforms, increasing its reach and





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accessibility to previously unheard-of heights. Neil Gaiman pointed out quite wisely "You can search for 100,000 solutions on Google. You can get the appropriate one back from a librarian." This section examines how the digital age has affected literary discourse evolution and patterns of literary consumption. We find new avenues for literary engagement, creative expression, and cooperative storytelling by looking at the nexus between technology and literature. Digital platforms have made literature more accessible to all people and have given marginalized voices a worldwide audience. Literature is now a more dynamic and interactive field because of the growth of new literary criticism and discussion formats supported by social media and online communities. But there are drawbacks to this digital revolution as well. Traditional publishing is in decline, and there is the issue of whether digital content is as permanent as printed books.

Literature as a Cultural Artifact

Literature is a cultural artifact that captures the spirit of the times it is written in and provides insights into the sociopolitical forces that shape its production and reception. This purpose of writing is strengthened in the digital age as a wider range of voices and experiences are captured by digital platforms. Works that are released digitally or online frequently address current challenges of accessibility and immediacy in a way that traditional print media cannot equal.

For example, the emergence of self-publishing platforms has made it possible for writers from a variety of backgrounds to tell their experiences without traditional publishing's gatekeeping. Modern digital literature can work as a more representative and inclusive cultural artifact, representing the diversity of human experiences and identities, as a result of the democratization of literary production.

Digital Consumption and Cultural Materialism

The way that people read literature in the digital age is also a reflection of larger cultural and economic changes. The emergence of electronic books, audiobooks, and virtual literary communities has revolutionized reading practices, increasing accessibility to literature but simultaneously altering the nature of literary consumption. We are prompted to think about the economic effects of these shifts by cultural materialism. The old publishing businesses have been shaken by the growth of digital platforms, posing a challenge to the economic models that have long supported literary production. This change raises concerns about the worth of literary work in the digital age when digital content is frequently assumed to be free or inexpensive, as well as the viability of literary careers in this context.

Furthermore, new literary expressions have emerged in the digital age, like transmedia storytelling and interactive fiction, which combine text and multimedia components. These developments show how cultural objects are changing in a digital age when technology and literature combine to produce new forms of narrative.

The Significance of Grammar in Literary Expression

Even though the emergence of digital communication has changed the literary expression environment, grammatical principles are still essential for good narrative. Grammar proficiency raises the caliber of literary workmanship and increases reader engagement, as shown in the spare elegance of Ernest Hemingway and the lyrical prose of Toni Morrison. According to Mark Twain, "The difference between the almost right word and the right word is a large matter—'tis the difference between the lightning-bug and the lightning." We demonstrate how adherence to grammatical principles improves readability, coherence, and narrative effect in literature through a detailed analysis of stylistic choices and grammatical standards.

Grammar is the framework of literature; it provides the order necessary for expression and creativity. The use of proper grammar guarantees accuracy and clarity, which helps writers to communicate difficult concepts and feelings. "Writing is an act of faith, not a trick of grammar, but it is not complete without the trick," as E.B. White said.



**Sathees Kumar****Literature as a Catalyst for Personal Growth and Self-Reflection**

Beyond its role as a source of entertainment and enlightenment, literature catalyzes personal growth and self-reflection, inviting readers to confront existential questions and navigate the complexities of the human condition. From the bildungsroman of J.D. Salinger's *The Catcher in the Rye* to the philosophical musings of Hermann Hesse's *Siddhartha*, literature provides a mirror for introspection and a compass for moral exploration. As Marcel Proust famously wrote, "The real voyage of discovery consists not in seeking new landscapes, but in having new eyes." Through an exploration of literary themes such as identity, alienation, and the search for meaning, we highlight literature's transformative potential in shaping individual perspectives and fostering emotional resilience.

Novels like Elizabeth Gilbert's *Eat, Pray, Love* and Khaled Hosseini's *The Kite Runner* and other works that lead readers through themes of self-discovery, forgiveness, and redemption are prime examples of how literary characters' journeys reflect personal growth and provide readers with a means of navigating their own lives.

The Global Impact of English Literature

English literature has a special role in influencing cross-cultural interactions and promoting intercultural conversation because it is the universal language of communication worldwide. English literature has a global readership that transcends linguistic boundaries, from Chinua Achebe's postcolonial novels to William Shakespeare's timeless sonnets. The wise words of Maya Angelou once said, "We are more alike, my friends than we are unlike." This section traces the development of English literature across time and its ongoing contribution to the spread of global topics and the elevation of various voices. We celebrate the diversity and richness of the world's literary history by studying the works of both classic writers and modern voices, reaffirming literature's function as a unifying force across cultural divides and a witness to the universal human condition. The fact that English literature is read all over the world attests to its adaptability and relevance. English-language writers with varied cultural backgrounds, such as Arundhati Roy and Kazuo Ishiguro, demonstrate how English literature is still evolving and how it shapes and reflects global narratives.

CONCLUSION

In summary, literature continues to be a vital component of human civilization, providing comfort, knowledge, and inspiration to all ages. In the words of Frederick Buechner, "The place God calls you to is the place where your deep gladness and the world's deep hunger meet." We deepen our comprehension of the human condition and reinforce the ongoing significance of literary expression in determining our common destiny when we engage with literature as both an art form and a cultural artifact. Literature offers insights into the human condition and inspires revolutionary change, helping us through the complexity of the modern world. We may address existential issues, refute established ideas, and rethink possibilities for a world that is more just and equal through literature. As Albert Camus famously said, "I finally discovered that there was an unstoppable summer inside of me in the depths of winter." Let us continue to explore the great world of literature in this spirit of resiliency and rebirth, finding strength in its eternal wisdom and collective imagination.

REFERENCES

1. Lewis, C.S. *An Experiment in Criticism*. Cambridge: Cambridge University Press, 1961.
2. Atwood, Margaret. *The Handmaid's Tale*. Boston: Houghton Mifflin, 1985.
3. Lee, Harper. *To Kill a Mockingbird*. Philadelphia: J.B. Lippincott & Co., 1960.
4. Tolstoy, Leo. *Anna Karenina*. Translated by Richard Pevear and Larissa Volokhonsky, Penguin Classics, 2000.
5. Camus, Albert. *The Stranger*. Translated by Matthew Ward, Vintage International, 1989.
6. Twain, Mark. *The Adventures of Huckleberry Finn*. New York: Charles L. Webster And Company, 1884.
7. White, E.B. *The Elements of Style*. With William Strunk Jr., New York: Macmillan, 1959.





Sathees Kumar

8. Proust, Marcel. *In Search of Lost Time*. Translated by C.K. Scott Moncrieff and Terence Kilmartin, Modern Library, 1998.
9. Shakespeare, William. *The Complete Works of William Shakespeare*. London: Wordsworth Editions, 1996.
10. Mar, Raymond A., Keith Oatley, and Jordan B. Peterson. "Exploring the link between reading fiction and empathy: Ruling out individual differences and examining outcomes." *Communications*, vol. 34, no. 4, 2009, pp. 407-428.
11. Baldwin, James. *The Fire Next Time*. New York: Dial Press, 1963.
12. Bukowski, Charles. *The Last Night of the Earth Poems*. Santa Rosa: Black Sparrow Press, 1992.
13. Gaiman, Neil. *The View from the Cheap Seats: Selected Nonfiction*. New York: William Morrow, 2016.
14. Twain, Mark. *Mark Twain's Letters, Volume 6: 1874-1875*. Edited by Michael B. Frank and Harriet Elinor Smith, Berkeley: University of California Press, 2002.
15. Greenblatt, Stephen. *Renaissance Self-Fashioning: From More to Shakespeare*. Chicago: University of Chicago Press, 1980.
16. Gold, Matthew K., and Lauren F. Klein, eds. *Debates in the Digital Humanities*. Minneapolis: University of Minnesota Press, 2016.
17. Rushdie, Salman. *Imaginary Homelands: Essays and Criticism 1981-1991*. London: Granta Books, 1991.





Investigation into Crop Yield Survival Rates using Various Casting Techniques with Agricultural Data

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ABSTRACT

Agriculture is a cornerstone of the Indian economy, heavily reliant on crop production. Central to maintaining a prosperous agricultural sector is the accurate identification of plant diseases, crucial for preventing wastage of resources and money. Additionally, predicting crop yields is vital for informed decision-making in agricultural risk management. Despite numerous classification and prediction methods explored, achieving high accuracy levels and reducing time complexity in crop yield forecasting remains a challenge. To tackle these issues, various machine learning and deep learning techniques have been scrutinized for their potential in enhancing crop yield prediction efficiency.

Keywords: Agriculture, plant disease identification, risk management, deep learning, crop yield history

INTRODUCTION

Agriculture is a significant contributor to India's economic growth. The rising population of country and constantly changing climatic conditions has an impact on crop production and food security. Agriculture is extremely important one to the global economy. Farmers adopt good crop yield prediction to decide what to plant and when to plant it. The global crop yield is an essential one for addressing the food security problems and for mitigating the climate change effects as the human population grow. Crop yield forecasting is a significant agricultural problem. Weather conditions and pesticides have great impact on agricultural yield. It is an essential to perform accurate knowledge



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regarding the crop yield history while making decisions about agricultural risk management and yield forecasting. Crop yield prediction is a demand for decision-makers at all levels including global and local levels. Crop yield prediction is an essential task for the decision-makers at national and regional levels for decision-making. This paper is arranged as: Section 2 reviews the drawbacks on existing crop yield prediction methods. Section 3 shows the study and analysis of existing crop yield prediction methods. Section 4 identifies the possible comparison between them. Section 5 explains the limitations of existing crop yield prediction techniques. The conclusion of paper is discussed in the section 6.

LITERATURE SURVEY

A crop yield forecasting model was introduced in [1] for sub-regional yield prediction with remote sensing time series data and crop model. Parameter distributions were carried out to classify the agricultural heterogeneity. However, the accuracy level was not improved by designed crop yield forecasting model. An ensemble machine learning algorithm was designed in [2] with wild blueberry dataset. The features employed best regulation for wild blueberry agro-ecosystems. Bayesian optimization was carried out to attain the best hyper-parameters for accurate wild blueberry yield prediction. However, the classification time was not reduced by ensemble machine learning algorithm. Moderate Resolution Imaging Spectroradiometer (MODIS) vegetation indices- and phenology-based yield prediction generalization model was introduced in [3] with US Corn Belt. Depending on time series, VI change rate (dVI) time series was determined to calculate crop growth rate. But, the error rate was not minimized by MODIS vegetation indices. Fuzzy Enumeration Crop Prediction Algorithm (FECPA) was designed in [4] for accurate crop yield prediction. FECPA developed programs for efficient data classification. Preprocessing analyzed the collected data and identified the absent values for the attribute. However, the accuracy level was not improved by FECPA. A Bayesian domain adversarial neural network (BDANN) was designed in [5] for unsupervised domain adaptation (UDA) during corn yield prediction. BDANN reduced the domain shift and predict corn yield through domain-invariant and task-informative features from target domains. But, the space complexity was not taken into consideration. A robust plant disease classification system was designed in [6] with Custom CenterNet framework and DenseNet-77. An improved CenterNet was designed with DenseNet-77 for deep keypoints extraction.

A one-stage detector CenterNet detected and categorized the plant diseases. But, the computational complexity was not minimized by designed system. A multi-layered perceptron model was introduced in [7] for disease classification to identify the plant disease and to increase production drastically. The real-time data was captured through soil sensors system at agriculture field for micro-meteorological factors. However, the time complexity was not minimized by multi-layered perceptron model. Quantile Regressive Empirical correlative Functioned Deep Feed Forward Multilayer Perceptron Classification (QRECF-DFFMPC) Method was introduced in [8] for crop yield prediction. Empirical Orthogonal Function was employed to choose the relevant features with orthogonal basis functions. Quantile regression examined the features and produced the regression value for every data point. Though prediction accuracy was improved, the computational coat was not minimized. Machine Learning (ML) algorithm was introduced in [9] for winter wheat yield prediction. The polynomial function described the water and nitrogen application with winter wheat yield and dry matter. However, the computational cost was not minimized through ML algorithm. Recurrent neural networks (RNN) termed Seq2Seq architecture was introduced in [10] to predict the probable scenarios of crop rotations in subsequent seasons with cropping habits. The crop model was used with decision support system for agricultural production to select the compromise between profitability and environmental impacts. However, the space complexity was not minimized by Seq2Seq architecture. An efficient deep-learning technique was designed in [11] for cocoa yield prediction. A deep learning approach was employed for cocoa yield prediction with Convolutional Neural Network and Recurrent Neural Network (CNN-RNN). Though the accuracy level was improved, the time complexity was not taken into consideration. A crop yield forecasting approach was introduced in [12] for multiple spatial levels depending on regional crop yield forecast from machine learning. A generic machine learning workflow was carried out to perform regional crop yield forecasting in Europe. But, the error rate was not minimized during crop yield forecasting.



**Karkuzhali and Padmapriya****CROP YIELD FORECASTING WITH AGRICULTURAL DATA**

Agriculture is the backbone of Indian Economy. In India, many farmers are not attaining the expected crop yield because of different reasons. The farmers require advice to forecast the crop productivity. The data volume is enormous in Indian agriculture. The data when become information is highly useful for many purposes. Data Mining is used to analyze the large dataset and perform efficient classifications and patterns in datasets. Data mining process is used to extract the information and transform into understandable structure for further use. Deep data analysis is carried out to help farmers for increasing the crop production in their crops. Yield prediction is an important agricultural problem. Every farmer has an interest to know about their crop yield. The yield prediction is carried out through considering farmer's previous experience on particular crop.

Improving crop yield prediction accuracy by embedding phenological heterogeneity into model parameter sets

A crop yield forecasting model was introduced based on remote sensing (RS) time series data. A new forecasting model was designed for performing sub-regional yield prediction with RS time series data and crop model. The designed model was to release the process. The heterogeneity of agricultural landscape observed from RS was employed to drive the crop model calibration. Fine-resolution barley and maize distribution maps were employed to derive the time series data positioned in Apulia, Tuscany, and Veneto in 2018–2019. Principal Component Analysis and Hierarchical Clustering were applied to NDVI seasonal profiles to classify the agrophenotypes to derive crop growth and leaf area index dynamics. The data was employed to optimize the relevant parameters using gridded weather data. Parameter distribution from several automatic calibrations was sampled to differentiate the agricultural heterogeneity within administrative units. Yield statistics were used to test the accuracy of the yield simulation by the crop model. A new forecasting approach was employed to enhance the precision of crop yield predictions through incorporating vegetation temporal and spatial dynamics into crop model simulations. The designed model was employed to automate the crop yield prediction accuracy at NUTS-2 and NUTS-3 levels. The workflow involves processing NDVI time series to identify clusters of pixels with similar growth dynamics in 2018–2019 to obtain phenological stages and LAI data for crop model calibration.

Ensemble Machine Learning Techniques Using Computer Simulation Data for Wild Blueberry Yield Prediction

An ensemble machine learning algorithm was introduced to increase the forecast accuracy of best characteristics for addressing the challenges. A stacking regression (SR) and cascading regression (CR) was employed with MLA depending on wild blueberry dataset. The features indicated best regulation for wild blueberry agro-ecosystems. The feature engineering selection method namely variance inflation factor (VIF), sequential forward feature selection (SFFS), sequential backward elimination feature selection (SBEFS) and extreme gradient boosting depending on feature importance (XFI). Bayesian optimization was employed to identify the best hyperparameters for accurate wild blueberry yield prediction. SR employed two-layer structure like level-0 containing light gradient boosting machine (LGBM), gradient boost regression (GBR) and extreme gradient boosting (XGBoost) and level-1 for output prediction with Ridge. CR topology was similar to MLA used in series form as feeder to every MLA and removed efficient prediction in every stage.

A generalized model to predict large-scale crop yields integrating satellite-based vegetation index time series and phenology metrics

Moderate Resolution Imaging Spectroradiometer (MODIS) vegetation indices- and phenology-based yield prediction generalization model was introduced with US Corn Belt. The normalized difference vegetation index (NDVI) and 2-band enhanced vegetation index (EVI2) time series were adjusted with greenup dates from Land Cover Dynamics product MCD12Q2. Depending on adjusted VI (NDVI, EVI2) time series, the VI change rate (dVI) time series was calculated for increasing the crop growth rate. The initial step cluster the adjusted VI and dVI time series termed greenup groups consistent with corresponding greenup dates in five-day interval. In different greenup groups, an empirical univariate models with VI were employed with maximum correlation for better crop yield. The multivariate models with VI and dVI were used to construct the generalized model. After clustering process, the days with maximum VI correlation decreased when greenup days increased. A univariate VI model and multivariate VI as well as dVI model performance gets improved in different groups. MODIS vegetation indices- and phenology-





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based yield prediction generalization model was convenient and scalable with limited data requirements and date-determined variables after green up. The designed model provided generalized method to forecast the crop yields at large scale before harvest with better performance.

Superior fuzzy enumeration crop prediction algorithm for big data agriculture applications

Superior fuzzy enumeration crop prediction algorithm was introduced to increase the crop yield prediction accuracy from agricultural data through data classification. Preprocessing was employed to examine the collected data and recognize the absent values for attribute. Non-existent values were filled with equivalent new values through verifying the previous and past results. The fuzzy strategy was the right dimension through reducing the strategy to highlight any self-organizing contours. After minimizing the dimension, the reduced dimension information was employed to forecast the climate as a reasonable result. An advanced methodology termed Fuzzy Enumeration Crop Prediction Algorithm (FECPA) was employed for efficient crop yield prediction. FECPA improved the productivity of different sources through data analysis, predictive analysis and crop production. FECPA increased the farmers developing a system of integrated data in long trip profit margins. FECPA improved the crop yield prediction accuracy with minimal time consumption for big data agriculture applications.

PERFORMANCE ANALYSIS OF CROP YIELD PREDICTION TECHNIQUES

In order to compare the crop yield prediction techniques, number of agricultural data points is taken as input to conduct the experiment. Experimental evaluation of four techniques, namely crop yield forecasting model, ensemble machine learning algorithm, MODIS vegetation indices- and phenology-based yield prediction generalization model and Fuzzy Enumeration Crop Prediction Algorithm (FECPA) are implemented using Java language. In order to predict the crop yield, Soybean (Large) Data Set is taken from the UCI Repository. The URL of mentioned dataset is given as <https://archive.ics.uci.edu/dataset/90/soybean+large>. The dataset comprises 35 categorical attributes, some nominal and some ordered. The values for attributes are encoded numerically with the first value encoded as “0” the second as “1” and so on. The dataset comprises 307 data instances with multivariate characteristics. The associated task of the dataset is classification. Result analyses of existing crop yield prediction techniques are computed with parameters are,

- Prediction Accuracy
- Prediction Time and
- Error Rate

Result Analysis on Prediction Accuracy

Prediction accuracy is defines as the ratio of number of agricultural data points that correctly predicts the crop yield to the total number of agricultural data points taken as input. The prediction accuracy ‘ P_A ’ is determined as,

$$P_A = \left(\frac{\text{Number of agricultural data points that are correctly predicted}}{\text{Number of agricultural data points}} \right) * 100 \quad (1)$$

From (1), the prediction accuracy is computed. The prediction accuracy is calculated in terms of percentage (%). Table 1 discusses the prediction accuracy comparison for four different existing methods. Table 1 explains the performance analysis of prediction accuracy for four different techniques, namely crop yield forecasting model, ensemble machine learning algorithm, MODIS vegetation indices- and phenology-based yield prediction generalization model and Fuzzy Enumeration Crop Prediction Algorithm (FECPA) with respect to number of agricultural data points ranging from 30 to 300. From above discussed table value, it is observed that prediction accuracy of ensemble machine learning algorithm is comparatively higher than other three existing methods. The graphical representation of prediction accuracy is illustrated in the figure 1. Figure 1 shows the prediction accuracy comparison on diverse number of agricultural data points. The blue color cone in figure represents the prediction accuracy of crop yield forecasting model. The brown color cone and green color cone denotes the prediction accuracy of ensemble machine learning algorithm and MODIS vegetation indices- and phenology-based yield prediction generalization model. The violet color cone symbolizes the prediction accuracy of FECPA correspondingly. It is clear





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that the prediction accuracy using ensemble machine learning algorithm is higher when compared to crop yield forecasting model, MODIS vegetation indices and phenology-based yield prediction generalization model and FECPA. This is due to application of using Bayesian optimization to identify the hyperparameters for exact wild blueberry yield prediction. SR employed two-layer structure for output prediction with Ridge. Therefore, the prediction accuracy of ensemble machine learning is increased by 9% when compared to the crop yield forecasting model, 15% when compared to the MODIS vegetation indices- and phenology-based yield prediction generalization model and 20% when compared to the FECPA.

Analysis on Prediction Time

Prediction time is described as the amount of time utilized for predicting the crop yield. It is product of number of agricultural data points and amount of time consumed for predicting the one agricultural data point. Therefore, the prediction time ' P_T ' is formulated as,

$$P_T = \text{Number of data} * \text{time consumed for predicting one agricultural data} \quad (2)$$

From (2), the prediction time is determined. The prediction time is computed in terms of milliseconds (ms). Table 2 discusses the prediction time comparison for four different existing methods. Table 2 describes the performance analysis of prediction time for four different techniques, namely crop yield forecasting model, ensemble machine learning algorithm, MODIS vegetation indices- and phenology-based yield prediction generalization model and Fuzzy Enumeration Crop Prediction Algorithm (FECPA) with respect to number of agricultural data points ranging from 30 to 300. From above discussed table value, it is observed that prediction time of MODIS vegetation indices- and phenology-based yield prediction generalization model is comparatively lesser than other three existing methods. The graphical representation of prediction time is shown in figure 2. Figure 2 shows the prediction time comparison on diverse number of agricultural data points. The blue color cone in figure represents the prediction time of crop yield forecasting model. The brown color cone and green color cone denotes the prediction time of ensemble machine learning algorithm and MODIS vegetation indices- and phenology-based yield prediction generalization model. The violet color cone symbolizes the prediction time of FECPA correspondingly. It is shown that the prediction time using MODIS vegetation indices- and phenology-based yield prediction generalization model is lesser when compared to crop yield forecasting model, ensemble machine learning algorithm and FECPA. This is because of using generalized method to forecast the crop yields at large scale before harvest with better performance. MODIS vegetation indices- and phenology-based yield prediction generalization model was convenient and scalable with limited data requirements and date-determined variables after greenup. Therefore, the prediction time of MODIS vegetation indices- and phenology-based yield prediction generalization model is reduced by 43% when compared to the crop yield forecasting model, 22% when compared to the ensemble machine learning and 35% when compared to the FECPA.

Analysis on Error rate

Error rate is defined as the ratio of number of agricultural data points that are incorrectly predicted crop yield to the total number of agricultural data points taken as input. Consequently, the error rate ' E_R ' is determined as,

$$E_R = \left(\frac{\text{Number of data points that are incorrectly predicted crop yield}}{\text{Number of agricultural data points}} \right) * 100 \quad (3)$$

From (3), the error rate is determined. The error rate is computed in terms of percentage (%). Table 3 shows the performance analysis of error rate for four different techniques, namely crop yield forecasting model, ensemble machine learning algorithm, MODIS vegetation indices- and phenology-based yield prediction generalization model and Fuzzy Enumeration Crop Prediction Algorithm (FECPA) with respect to number of agricultural data points ranging from 30 to 300. From above discussed table value, it is shown that error rate of FECPA is comparatively lesser than other three existing methods. The graphical representation of error rate is shown in figure 3. Figure 3 illustrates the error rate depending on diverse number of agricultural data points. The blue color cone in figure represents the error rate of crop yield forecasting model. The brown color cone and green color cone denotes the error rate of ensemble machine learning algorithm and MODIS vegetation indices- and phenology-based yield prediction generalization model. The violet color cone symbolizes the error rate of FECPA correspondingly. It is observed that the error rate using FECPA is lesser when compared to crop yield forecasting model, ensemble machine learning algorithm and MODIS vegetation indices- and phenology-based yield prediction generalization



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model. This is due to the application of fuzzy strategy in right dimension through minimizing the strategy to highlight any self-organizing contours. After minimizing the dimension, the reduced dimension information forecast the climate as a reasonable result with minimal error rate. Consequently, the error rate of FECPA is reduced by 65% when compared to the crop yield forecasting model, 54% when compared to the ensemble machine learning and 33% when compared to the MODIS vegetation indices- and phenology-based yield prediction generalization model.

DISCUSSION ON LIMITATIONS OF CROP YIELD FORECASTING METHODS WITH AGRICULTURAL DATA

Crop yield forecasting model was introduced for performing sub-regional yield predictions using RS time series data. Analysis and Hierarchical Clustering applied NDVI seasonal profiles to derive the crop growth with leaf area index dynamics. Parameter distribution from multiple automatic calibrations characterized the agricultural heterogeneity within administrative units. But, the accuracy level was not improved by designed crop yield forecasting model. Bayesian optimization on machine learning algorithm was used to attain best hyperparameters for wild blueberry yield prediction. SR employed two-layer structure, namely level-0 containing light gradient boosting machine and extreme gradient boosting (XGBoost) for output prediction through Ridge. CR topology was used in series form and removed the previous prediction in every stage. However, the classification time was not reduced by ensemble machine learning algorithm. MODIS vegetation indices- and phenology-based yield prediction generalization model was introduced for performing US Corn prediction. The normalized difference vegetation index (NDVI) and 2-band enhanced vegetation index (EVI2) time series were adjusted from Land Cover Dynamics. A generalized method was employed to predict the crop yields at large scale before harvest with good performance. MODIS data was convenient and scalable with limited data requirements and date-determined variables. But, the error rate was not minimized by MODIS vegetation indices. FECPA was introduced for performing accurate crop yield prediction. The fuzzy strategy was the right dimension for reducing the strategy to emphasize any self-organizing contours. FECPA with increasing farmers developed the system of integrated data in long trip profit margins. FECPA improved the crop yield prediction accuracy. But, the time complexity was not minimized by FECPA.

Future Direction

The future direction of study is to perform efficient crop yield prediction with higher accuracy rate and lesser time consumption by using machine learning and deep learning techniques.

CONCLUSIONS

A comparison of different crop yield prediction techniques is studied. From the study, it is clear that the error rate was not minimized by MODIS vegetation indices. The time complexity was not minimized by FECPA. In addition, the prediction accuracy level was not improved by designed crop yield forecasting model. The wide range of experiment on existing crop yield prediction methods determines the performance results with its limitations. Finally, from the result, the research work can be carried out using machine learning and deep learning techniques for improving the performance of crop yield prediction with higher accuracy and lesser time complexity.

REFERENCES

1. Simone Bregaglio, Fabrizio Ginaldi, Elisabetta Raparelli, Gianni Fila and Sofia Bajocco, "Improving crop yield prediction accuracy by embedding phenological heterogeneity into model parameter sets", *Agricultural Systems*, Elsevier, Volume 209, June 2023, Pages 1-15
2. Hayam R. Seireg, Yasser M. K. Omar, Fathi E. Abd El-Samie, Adel S. El-Fishawy and Ahmed Elmahalawy, "Ensemble Machine Learning Techniques Using Computer Simulation Data for Wild Blueberry Yield Prediction", Volume 10, 2022, Pages 64671-64687





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3. Zhonglin Ji, Yaozhong Pan, Xiufang Zhu, Dajuan Zhang and Jinyun Wang, “A generalized model to predict large-scale crop yields integrating satellite-based vegetation index time series and phenology metrics”, *Ecological Indicators*, Elsevier, Volume 137, April 2022
4. P. Velmurugan, A. Kannagi and M. Varsha, “Superior fuzzy enumeration crop prediction algorithm for big data agriculture applications”, *Materials Today: Proceedings*, Elsevier, 2021, Pages 1-6
5. Yuchi Ma and Zhou Zhang, “A Bayesian Domain Adversarial Neural Network for Corn Yield Prediction”, *IEEE Geoscience and Remote Sensing Letters*, Volume 19, Issue 5513705, October 2022, Pages 1-15
6. Waleed Albattah, Marriam Nawaz, Ali Javed, Momina Masood and Saleh Albahli, “A novel deep learning method for detection and classification of plant diseases”, *Complex & Intelligent Systems*, Springer, Volume 8, 2022, Pages 507–524
7. Manish Kumar; Ahlad Kumar; Vinay S. Palaparthi, “Soil Sensors-Based Prediction System for Plant Diseases Using Exploratory Data Analysis and Machine Learning”, *IEEE Sensors Journal*, Volume 21, Issue 16, 15 August 2021, Pages 17455 - 17468
8. V. Sivanantham, V. Sangeetha, Abeer Ali Alnuaim, Wesam Atef Hatamleh, Chundururu Anilkumar, Ashraf Atef Hatamleh and Dirar Sweidan, “Quantile correlative deep feedforward multilayer perceptron for crop yield prediction”, *Computers & Electrical Engineering*, Elsevier, Volume 98, March 2022, Pages 1-15
9. Ying Wang, Wenjuan Shi and Tianyang Wen, “Prediction of winter wheat yield and dry matter in North China Plain using machine learning algorithms for optimal water and nitrogen application”, *Agricultural Water Management*, Elsevier, Volume 277, March 2023, Pages 1-15
10. Ambre Dupuis, Camélia Dadouchi and Bruno Agard, “Methodology for multi-temporal prediction of crop rotations using recurrent neural networks”, *Smart Agricultural Technology*, Elsevier, Volume 4, August 2023, Pages 1-15
11. Sunday Samuel Olofintuyi, Emmanuel Ajayi Olajubu and Deji Olanike, “An ensemble deep learning approach for predicting cocoa yield”, *Heliyon*, Elsevier, Volume 9, Issue 4, April 2023, Pages 1-15
12. Dilli Paudel, Hendrik Boogaard, Allard de Wit, Marijn van der Velde, Martin Claverie, Luigi Nisini, Sander Janssen, Sjoukje Osinga and Ioannis N. Athanasiadis, “Machine learning for regional crop yield forecasting in Europe”, *Field Crops Research*, Elsevier, Volume 276, 1 February 2022, Pages 1-15

Table 1: Tabulation for Prediction Accuracy

Number of Agricultural Data Points	Prediction Accuracy (%)			
	Crop Yield Forecasting Model	Ensemble machine learning algorithm	MODIS vegetation indices- and phenology-based yield prediction generalization model	FECPA
30	83	90	79	76
60	85	92	81	78
90	88	95	83	81
120	90	97	85	83
150	88	96	84	81
180	86	94	82	79
210	83	93	80	77
240	81	90	77	74
270	84	92	79	72
300	86	93	82	75

Table 2: Tabulation for Prediction Time

Number of Agricultural Data Points	Prediction Time (%)			
	Crop Yield Forecasting Model	Ensemble machine learning algorithm	MODIS vegetation indices- and phenology-based yield prediction generalization model	FECPA
30	83	90	79	76
60	85	92	81	78
90	88	95	83	81
120	90	97	85	83
150	88	96	84	81
180	86	94	82	79
210	83	93	80	77
240	81	90	77	74
270	84	92	79	72
300	86	93	82	75





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30	40	25	17	32
60	42	28	21	35
90	43	31	22	37
120	45	33	25	40
150	47	36	27	43
180	50	39	30	46
210	52	40	33	49
240	55	42	35	50
270	58	44	38	52
300	61	47	40	55

Table 3:Tabulation for Error rate

Number of Agricultural Data Points	Error Rate (%)			
	Crop Yield Forecasting Model	Ensemble machine learning algorithm	MODIS vegetation indices- and phenology-based yield prediction generalization model	FECPA
30	33	26	19	11
60	36	28	21	13
90	39	31	25	15
120	37	29	23	12
150	35	27	21	9
180	37	25	19	11
210	38	28	17	13
240	40	31	18	15
270	42	33	20	18
300	45	36	23	20

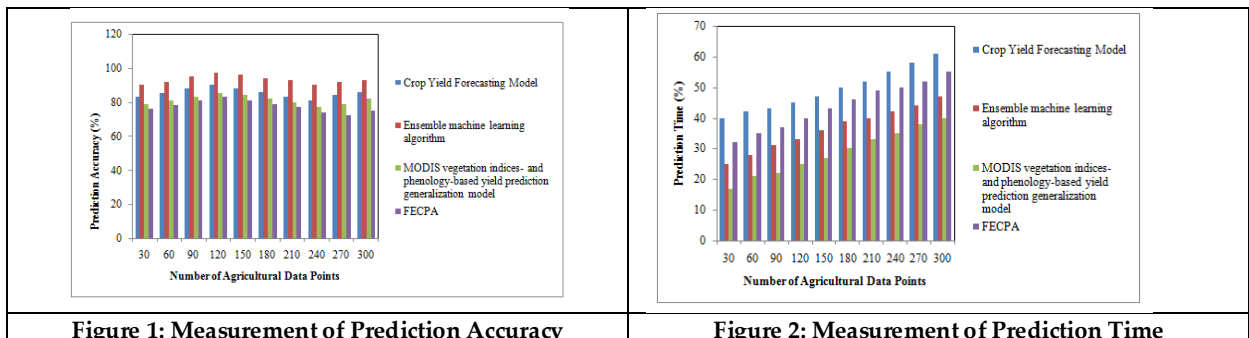


Figure 1: Measurement of Prediction Accuracy

Figure 2: Measurement of Prediction Time

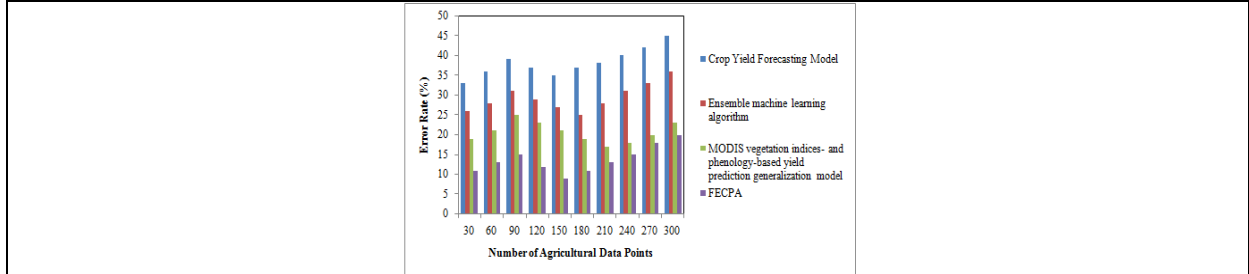


Figure 3: Measurement of Error Rate





Efficient Bird Species Classification: A Deep Learning Approach

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ABSTRACT

The incorporation of artificial intelligence (AI) techniques has completely transformed animal conservation initiatives, offering researchers and conservationists unparalleled insights and resources. In this field, there are several applications of AI that show great potential. Two notable approaches are deep convolutional neural networks (CNNs) and transfer learning. This paper explores the utilisation of advanced AI techniques to classify different bird species, with the goal of making a meaningful contribution to the conservation of avian fauna. In light of the increasing dangers to ecosystems and the concerning rates of species extinction, it has become crucial to comprehend and tackle the intricacies of biodiversity conservation. This study offers valuable insights into the application of AI for wildlife conservation by delving into the technical intricacies of employing CNNs for bird categorization. It explores the datasets, pre-processing procedures, and model architectures utilised, providing a detailed understanding of the topic. This research aims to provide conservationists with the necessary tools and insights to address the complex challenges facing avian biodiversity in today's world. By combining advanced AI techniques with comprehensive ornithological datasets, we hope to make a significant contribution to the field. In addition, the model's evaluation results are showcased, encompassing test accuracy, loss, precision, recall, and F1 score. These metrics offer a thorough evaluation of the model's ability to predict bird species across different categories.





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Keywords: Artificial intelligence (AI), Convolutional neural networks (CNNs), Bird species classification, Wildlife conservation, Transfer learning

INTRODUCTION

Over the past few years, the implementation of artificial intelligence (AI) has brought about a revolution in the field of animal conservation. This revolution has provided academics and conservationists with insights and techniques that have never been seen before. The classification of animal species through the utilisation of deep convolutional neural networks (CNNs) and transfer learning techniques is one of the most promising and significant areas of artificial intelligence in this sector, among the several applications of AI that are currently being developed. In order to help to the preservation and protection of avian fauna, this research investigates the application of these modern artificial intelligence approaches for the purpose of classifying bird species. Deep learning is utilised to bring about this classification. The conservation of animals, particularly bird species, is of the utmost importance in light of the alarming rates at which ecosystems are being destroyed, climate change is occurring, and humans are encroaching on natural areas. With an estimated 30,000 species that are in risk of extinction around the globe, it is of the utmost importance to gain an understanding of the reasons that contribute to their extinction and to put into practice conservation measures that are effective. The application of artificial intelligence provides a set of tools and capabilities that are significant in addressing these difficulties. When it comes to wildlife research, artificial intelligence makes it possible for researchers to obtain insights on the distribution, behaviour, and population dynamics of a wide variety of animal species through the collecting and analysis of huge datasets. Through the utilisation of artificial intelligence algorithms, researchers are able to categorise and identify animal species with an exceptional level of precision, which enables them to better monitor and preserve fragile populations.

Furthermore, prediction models that are powered by artificial intelligence are able to forecast animal trends, follow migration routes, and even predict the probability of extinction for endangered species. This information is extremely helpful for conservation planning and action. In this study, we explore into the technical aspects of using deep convolutional neural networks (CNNs) for bird categorization. Particularly, we make use of transfer learning to make use of pre-trained models in order to achieve quick and reliable species identification. In this paper, we investigate the conceptual framework and training techniques of convolutional neural networks (CNNs), as well as the process of fine-tuning pre-trained models to meet the specific requirements of bird categorization tasks. Furthermore, we explore the difficulties and opportunities that are inherent in the utilisation of artificial intelligence for the conservation of wildlife, stressing the potential impact that these technologies could have in reducing threats to the biodiversity of birds. The purpose of this work is to make a contribution to the ongoing efforts to protect avian species and the ecosystems in which they live by merging cutting-edge artificial intelligence techniques with the vast amounts of data that are accessible in the field of ornithology. By making improvements in bird categorization through the use of deep convolutional neural networks (CNNs) and transfer learning, our goal is to equip conservationists with the skills and insights they need to handle the complex challenges that are currently confronting avian biodiversity in the 21st century. In recent years, Convolutional Neural Networks have emerged as a highly effective instrument for the classification of birds [1].

Using picture data, these networks have demonstrated a significant amount of potential for reliably categorising different kinds of birds. The architecture of the CNN is made up of several layers, some of which being convolutional, pooling, and dense layers. A process known as feature extraction is carried out by the convolutional layers. This process involves applying filters to the input images in order to capture certain patterns and characteristics that are characteristic of particular bird species. When it comes to the categorization of birds, CNNs have been shown to be effective in capturing intricate patterns and features from photos of birds, which enables precise classification of various kinds of birds. When it comes to multi-class classification, the dense layer is responsible for producing the output as the dot product of the input and the kernel. This is then followed by a





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softmax layer providing the activation function. Through the use of a dataset consisting of bird photos, the CNN model may be trained, with each image being labelled with the species to which it belongs. Through the process of training, the model acquires the ability to recognise and differentiate between various kinds of birds. This is accomplished by modifying the weights of its filters and optimising its performance through iterations. Within the framework of the implementation procedure, the model is trained on a predetermined batch size and a predetermined number of epochs (in this example, fifty). The performance of the model is evaluated at the beginning of each epoch depending on the accuracy of its training and validation sessions. The accuracy and loss of the model can be plotted once the training history has been taken into consideration. It is also possible to utilise the `argmax()` function in order to display the prediction that the model has made and then compare it with the label that was initially assigned to the input image. It is therefore possible to use the CNN model that has been trained to categorise bird species based on new photos that are input. In the prediction made by the model, the species of the bird that has been recognised will be displayed beside the image that corresponds to it. Furthermore, the accuracy of the CNN model in identifying bird species can be improved by further research and development in the areas of bird species identification. There is potential for further enhancement of the CNN model's accuracy and performance through the implementation of a variety of deep learning techniques in the future.

PYTHON LIBRARIES USED FOR PROPOSED WORK

Here, we delve into the technical libraries and tools used in our deep learning framework for bird classification. These libraries make it easier to manipulate data, build models, train them, and evaluate their performance. **Data Science Libraries:** We incorporate crucial data science libraries such as NumPy, Pandas, and Matplotlib. Understanding the basics of data manipulation and analysis is crucial for any researcher. Tools like NumPy and Pandas provide a solid foundation for these tasks. Additionally, Matplotlib is a powerful tool that allows researchers to visualise data and evaluate model performance. **TensorFlow Libraries:** TensorFlow is a robust deep learning framework that is extensively utilised for constructing neural networks. We import TensorFlow and its submodules, including Keras, which offers a convenient API for constructing and training deep learning models. TensorFlow's layers module provides a wide range of neural network layers, models, optimizers, and callbacks that are essential for building and fine-tuning deep learning models. Utilising system libraries like Path from `pathlib` and `os.path`, we can effectively perform file and directory operations. These libraries allow for effective file management and manipulation of paths in the Python environment. Matplotlib and Seaborn are popular libraries used for creating plots and visualising data distributions. These libraries improve the understandability of findings and make it easier to gain insights into how well the model performs and the characteristics of the data. **Metrics:** Our evaluation of model performance involves utilising various metrics from the scikit-learn library, such as `classification_report` and `confusion_matrix`. These metrics offer valuable insights into the accuracy of classification, precision, recall, and F1-score. Additionally, they help visualise the confusion matrix to identify any weaknesses in the model.

TensorFlow Preprocessing Layers: The TensorFlow. keras. layers. experimental. preprocessing module offers convenient preprocessing layers that can be seamlessly incorporated into the model architecture. These layers facilitate effective data preprocessing, which involves tasks like normalisation, rescaling, and data augmentation. This helps improve the overall performance and generalisation of the model. The Image Data Generator class from the keras. preprocessing. image module is used to enhance the data during model training. Various techniques are used to enhance the training dataset, including rotation, zoom, and horizontal flipping. These methods help to improve the model's capacity to adapt to new and unfamiliar data. **Transfer Learning:** We utilise pre-trained models like MobileNetV2 from the TensorFlow. keras. applications module for transfer learning. Transfer learning allows us to utilise pre-trained models as feature extractors, harnessing the knowledge gained from extensive datasets and applying it to our particular bird classification task. Our deep learning framework for bird classification is enhanced with powerful features for data manipulation, model construction, training, and evaluation, thanks to the integration of these technical libraries and tools. These libraries facilitate the effective development and optimisation of deep learning models, which ultimately leads to precise and dependable bird species classification.





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THE DATASET DETAILS

This study makes use of a dataset that has a comprehensive collection of avian footage. This dataset demonstrates significant advancements in comparison to earlier versions. This revised version includes the addition of ten additional species, which in turn increases the dataset's amount of diversity and richness. In order to eliminate duplicate or near-duplicate images, stringent cleaning methods were applied using a powerful dataset analysis tool. This was done in order to guarantee the integrity of the data and prevent leakage between the training, testing, and validation subsets. In addition, photos with insufficient information and imperfections were painstakingly deleted, which resulted in a dataset consisting of 525 different species of birds that had been meticulously vetted. There is a sufficient amount of data for the training and evaluation of models thanks to the dataset, which contains 84,635 training photos, 2,625 test images (five images for each species), and 2,625 validation images (five images for each species). The fact that each picture contains a single bird that takes up at least fifty percent of the pixels makes it easier to do accurate classification jobs. Using the JPEG file format, all of the photos have been standardised to dimensions of 224 by 224 by 3, and discrete train, test, and validation sets have been organised into matching folders for the purpose of ensuring seamless integration with data generators. In addition, the dataset is accompanied by a metadata file called birds.csv. This file contains information that is relevant to the context of the dataset, including file locations, class labels, scientific names, dataset designation, and class indices. Particularly noteworthy is the fact that the test and validation photos were painstakingly chosen by hand in order to guarantee the best possible evaluation of the model. However, users have the ability to design their own subsets in order to conduct more robust evaluations. For the purpose of improving the interpretability and accuracy of the model, images were painstakingly obtained from internet searches, properly screened for duplicates, and then cropped and shrunk.

In spite of the immensity of the dataset, it is suggested that an image size of $150 \times 150 \times 3$ be utilised in order to speed up the training process without compromising performance. Although there is some variation in the number of files for each species in the training set, there are at least 130 photos for each species that are used for training, which guarantees that the model will be adequately trained. On the other hand, it is vital to emphasise that the dataset has a gender bias, with about 80 percent of the photos representing males and 20 percent depicting females. This could potentially have an effect on the performance of the classifier on photographs of female species. This part focuses on the loading and transformation of data for our bird species classification problem, utilising the TensorFlow deep learning framework. To start, we retrieve a collection of auxiliary functions from a GitHub repository that will assist us in doing various operations in our notebook. The functions encompass many utilities such as constructing Tensor Board callbacks, visualising loss curves, unzipping data, comparing training histories, browsing directories, and making predictions. Subsequently, we define the batch size and target size for our image data. The batch size sets the amount of samples processed in each iteration during model training, while the target size provides the dimensions to which all input photos will be scaled. For our specific situation, we have designated the batch size as 32 and the goal size as (224, 224). This means that we will be handling photographs in groups of 32 and adjusting their dimensions to a square shape measuring 224x224 pixels. Subsequently, we proceed to load and manipulate the data. The dataset is stored in the directory `./input/100-bird-species/train`, which consists of subdirectories representing various bird species. We employ a bespoke function, `walk_through_dir`, to systematically navigate the directory hierarchy and examine its contents. This function offers a comprehensive picture of the directory structure, presenting the count of files and subdirectories included within each directory.

Through the process of loading and processing the data, we get it ready for the following steps of model training and evaluation. This preliminary preprocessing stage establishes the groundwork for constructing a deep learning model that can effectively categorise bird species by analysing input photos. A pandas DataFrame is a flexible data structure extensively employed for data manipulation and analysis in Python. The DataFrame comprises two columns: "filepaths" and "labels." The "filepaths" column stores the specific file path of each image within the dataset directory. We employ the Path module from the Python pathlib package to effectively manage file paths. To recursively search for picture files with different extensions (e.g., .JPG, .jpg, .png) within the dataset directory, we utilise the `glob()` function. This method generates a list of file paths. The "labels" column represents the class label of each image, which is obtained from the file location. The label is obtained by utilising the `os.path.split()` function to divide the file





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path. This allows us to retrieve the name of the parent directory, which corresponds to the class label of the image. Once we have acquired the file paths and labels, we proceed to create two pandas Series objects to hold this data. We assign the column names 'Filepath' and 'Label' to appropriately label the columns. Afterwards, we combine these Series horizontally to create the picture DataFrame (image_df). In order to analyse the distribution of labels in the dataset, we calculate the frequency of each label using the value_counts() method. We prioritise the analysis of the 20 most often occurring labels and present their distribution in a bar plot. The seaborn library is employed to generate visually appealing and useful visualisations, where the x-axis labels reflect distinct bird species and the y-axis displays the frequency of occurrence. This technique allows us to obtain a thorough comprehension of the distribution of labels within the image dataset, offering useful insights into the composition and distribution of classes in the dataset. These insights are crucial for the following steps of model training, validation, and evaluation, guaranteeing the resilience and efficiency of our deep learning model for classifying bird species. Compressing a picture with JPEG at a specified quality level, compute_ela_cv() calculates the absolute difference between the compressed and original images. The scaled difference is returned as an ELA image. JPEG compression, absolute difference computation, and ELA image return are also performed by the convert_to_ela_image() function. This picture helps identify errors by showing differences between original and compressed photos. The random_sample() function takes a random file path from a directory to randomly select ELA photos. Finally, compute_ela_cv() generates ELA images using a randomly picked animal image from the test dataset. These ELA photos have varying compression-induced inaccuracy due to their decreasing quality. Matplotlib plots ELA pictures.

DATA PREPROCESSING

Preparing data for an image classification task that involves animals. Initially, the dataset is divided into training and testing sets by utilising the train_test_split function from scikit-learn. The test size is set at 20% and shuffling is enabled to ensure randomness. Afterwards, Image Data Generator objects are generated for both the training and testing data. Preprocessing functions are then applied to guarantee compatibility with the Efficient Netmodel. The data is divided into training and validation sets using the flow_from_dataframe method. This method reads data from the Data Frame and generates batches of augmented data. At last, the test data is processed using a distinct Image Data Generator instance. In general, this code segment establishes the data pipeline required for training and evaluating the image classification model.

MODELLING

The key the hyper parameters are listed below:

- Batch size: 32.
- Epochs: 100.
- Input shape: (224, 224, 3).
- Output layer: 525 classes (representing 525 bird species)

TensorFlow's Keras API is used to load the EfficientNetB0 model with the supplied input shape, however the top classification layer is not included. The weights are set to pre-trained ImageNet weights, and the global max pooling layer is added as the last layer. The pre-trained model's weights are frozen (pretrained_model.trainable = False) to prevent them from changing during training. This method is often used in transfer learning to employ pre-trained features without over fitting the new dataset. In addition, three callbacks are created to monitor the training process:

Model Checkpoint

Saves the model's weights after each epoch as the validation loss lowers, allowing the best performing model to be retrieved. Early Stopping: Stops training if the validation loss does not improve after a set number of epochs, preventing over fitting.

Tensor Board callback

Use TensorBoard to visualise and monitor training metrics, allowing for in-depth examination of model performance. The model is trained using the configured EfficientNetB0 architecture, which includes hyper parameters and





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callbacks. The Model Checkpoint callback is configured to save the model's weights after each epoch if validation accuracy increases, ensuring that the best-performing model is kept. The Early Stopping callback is used to monitor the validation loss measure and halt training if there is no progress after 5 epochs. When the best-performing model is terminated early, its weights are restored. The Reduce LR On Plateau callback is used to reduce the learning rate by 0.2 if the validation loss does not decrease for three consecutive epochs, which aids in fine-tuning the model's performance. The model architecture is built around the EfficientNetB0 basic model, with additional classification layers added. Data augmentation is performed on the supplied photos. For feature extraction and classification, additional dense layers with dropout regularisation are added to the model. The model is built using the Adam optimizer with a learning rate of 0.0001, a categorical cross entropy loss function, and an accuracy metric. Training is carried out using the fit() method, which specifies the training and validation data generators, as well as the number of epochs and validation steps. The defined callbacks monitor the training process, which includes early stopping, TensorBoard logging, model checkpointing, and learning rate decrease. Overall, this section manages the training of the EfficientNetB0 model for bird species categorization, with a focus on improving performance, avoiding overfitting, and utilising transfer learning approaches.

MODEL EVALUATION

During the evaluation phase of the technical paper, the test dataset is employed to evaluate the performance of the trained model. Diverse criteria are utilised to assess the efficacy of the model in reliably categorising bird species. Accuracy is a key metric that measures the ratio of true predictions made by the model. Furthermore, precision (P), recall (R), and F1 score (F1) are essential measures employed to thoroughly assess the model's performance:

Precision (P) is a metric that quantifies the accuracy of predictions by measuring the ratio of correct predictions (true positives, TP) to the total number of relevant findings, which includes both TP and false positives (FP). In the context of multi-class classification issues, precision is calculated by taking the average over all classes. The precision formula is expressed as follows: $p = \frac{TP}{TP+FP}$

where P represents precision, TP represents true positives, and FP represents false positives.

The recall (R) metric calculates the ratio of true positives (TP) to the sum of true positives (TP) and false negatives (FN), which indicates the proportion of missed predictions. Recall, like precision, is calculated as an average over all classes in multi-class classification. The F1 score, sometimes known as F1, is calculated as the harmonic mean of precision and recall. It offers an equitable evaluation of the model's effectiveness, taking into account both precision and recall concurrently. The F1 score, similar to accuracy and recall, is computed by taking the average across all classes in multi-class classification scenarios. The F1 score is calculated using the formula: $F1 = 2 \frac{(P \times R)}{P+R}$

RESULTS AND DISCUSSION

On the basis of the test dataset, the evaluate() method is utilised in order to evaluate the performance of the model. The numbers for test loss and test accuracy are stored in the variable 'results', which is where the evaluation results are stored. The test loss is supplied with a precision of five decimal places, while the accuracy is made available in the form of a percentage. A representation in graphical form of the development of loss values include: It is possible to extract the accuracy of the training and validation sets, as well as the loss of the training and validation sets, by making use of the history object that is produced during the process of training the model. Matplotlib is utilised in order to generate a plot that illustrates the correlation between the number of epochs and the values of accuracy and loss within the dataset. There are two unique plots that are generated: one illustrates the accuracy of the training and validation, and the other illustrates the loss of the training and validation. The plots provide vital insights into the learning process of the model by displaying the changes in accuracy and loss across epochs throughout the training and validation processes. These indicators together offer a comprehensive assessment of the model's categorization ability, guaranteeing a thorough evaluation of its usefulness in properly predicting bird species across several categories.





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CONCLUSION

The incorporation of artificial intelligence (AI) techniques has completely transformed animal conservation initiatives, offering researchers and conservationists unparalleled insights and resources. In this field, there are several applications of AI that show great potential. Two notable approaches are deep convolutional neural networks (CNNs) and transfer learning. This paper explores the utilisation of advanced AI techniques to classify different bird species, with the goal of making a meaningful contribution to the conservation of avian fauna. In light of the increasing dangers to ecosystems and the concerning rates of species extinction, it has become crucial to comprehend and tackle the intricacies of biodiversity conservation. This study offers valuable insights into the application of AI for wildlife conservation by delving into the technical intricacies of employing CNNs for bird categorization. It explores the datasets, preprocessing procedures, and model architectures utilised, providing a detailed understanding of the topic. This research aims to provide conservationists with the necessary tools and insights to address the complex challenges facing avian biodiversity in today's world. By combining advanced AI techniques with comprehensive ornithological datasets, we hope to make a significant contribution to the field. In addition, the model's evaluation results are showcased, encompassing test accuracy, loss, precision, recall, and F1 score. These metrics offer a thorough evaluation of the model's ability to predict bird species across different categories.

REFERENCES

1. Huang, Yo-Ping, and HaobijamBasanta. "Recognition of endemic bird species using deep learning models." *Ieee Access* 9 (2021): 102975-102984.
2. Niemi, Juha, and Juha T. Tantt. "Deep learning case study for automatic bird identification." *Applied sciences* 8.11 (2018): 2089.
3. Ragib, Kazi Md, et al. "Pakhichini: Automatic bird species identification using deep learning." *2020 Fourth world conference on smart trends in systems, security and sustainability (WorldS4)*. IEEE, 2020.
4. Ragib, Kazi Md, et al. "Pakhichini: Automatic bird species identification using deep learning." *2020 Fourth world conference on smart trends in systems, security and sustainability (WorldS4)*. IEEE, 2020.
5. Xie, Jie, and Mingying Zhu. "Handcrafted features and late fusion with deep learning for bird sound classification." *Ecological Informatics* 52 (2019): 74-81.
6. Bidwai, Piyush, et al. "Bird Classification using Deep Learning." *International Research Journal of Engineering and Technology (IRJET)* (2020).
7. Kumar, Akash, and SouryaDipta Das. "Bird species classification using transfer learning with multistage training." *Computer Vision Applications: Third Workshop, WCVA 2018, Held in Conjunction with ICVGIP 2018, Hyderabad, India, December 18, 2018, Revised Selected Papers 3*. Springer Singapore, 2019.
8. Huang, Yo-Ping, and HaobijamBasanta. "Bird image retrieval and recognition using a deep learning platform." *Ieee access* 7 (2019): 66980-66989.
9. Anusha, Pureti, and KundurthiManiSai. "Bird species classification using deep learning." *2022 International Conference on Intelligent Controller and Computing for Smart Power (ICICCSP)*. IEEE, 2022.
10. Raj, Satyam, et al. "Image based bird species identification using convolutional neural network." *International Journal of Engineering Research & Technology (IJERT)* 9.6 (2020): 346.
11. Kumar, Manoj, et al. "Bird Species Classification from Images Using Deep Learning." *International Conference on Computer Vision and Image Processing*. Cham: Springer Nature Switzerland, 2022.
12. Al-Showarah, Suleyman A., and Sohyb T. Al-qbailat. "Birds Identification System using Deep Learning." *International Journal of Advanced Computer Science and Applications* 12.4 (2021).
13. Weinstein, Ben G., et al. "A general deep learning model for bird detection in high-resolution airborne imagery." *Ecological Applications* 32.8 (2022): e2694.
14. Niemi, Juha, and Juha T. Tantt. "Deep learning-based automatic bird identification system for offshore wind farms." *Wind Energy* 23.6 (2020): 1394-1407.





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15. Islam, Shazzadul, et al. "Bird species classification from an image using VGG-16 network." *Proceedings of the 7th International Conference on Computer and Communications Management*. 2019.
16. Xie, JiangJian, et al. "Bird species recognition method based on Chirplet spectrogram feature and deep learning." *Journal of Beijing forestry university* 40.3 (2018): 122-127.
17. Denton, Tom, Scott Wisdom, and John R. Hershey. "Improving bird classification with unsupervised sound separation." *ICASSP 2022-2022 IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP)*. IEEE, 2022.
18. Raj, Satyam, et al. "Image based bird species identification using convolutional neural network." *International Journal of Engineering Research & Technology (IJERT)* 9.6 (2020): 346.
19. Swaminathan, Bhuvaneshwari, M. Jagadeesh, and SubramaniaswamyVairavasundaram. "Multi-label classification for acoustic bird species detection using transfer learning approach." *Ecological Informatics* 80 (2024): 102471.
20. Ferreira, André C., et al. "Deep learning-based methods for individual recognition in small birds." *Methods in Ecology and Evolution* 11.9 (2020): 1072-1085.

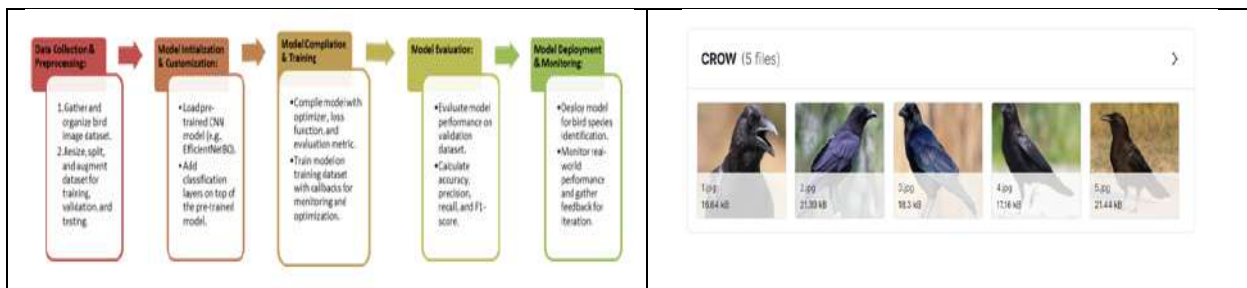


Figure 1 :Plan of action for the proposed method.



Figure 2. Sample dataset for the proposed method for one category of bird

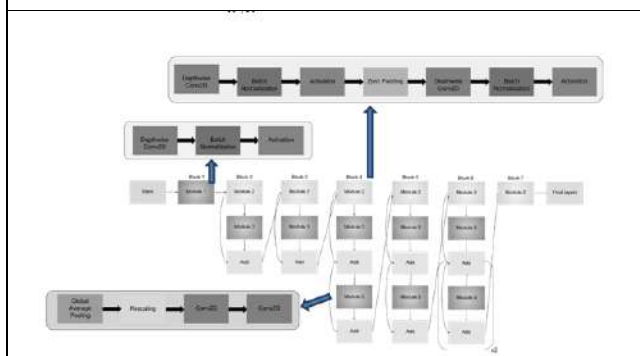


Figure 3: Proposed model Efficient Net B0 for bird classification

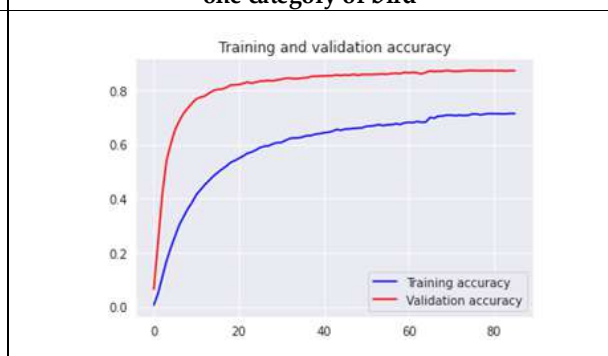


Figure 4: Training and validation accuracy of proposed method





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Figure 5: Training and validation loss of proposed method



Figure 6: Sample output of predicted birds with a different validation set

	precision	recall	f1-score	support
ABBOTTS BABBLER	0.866667	0.764706	0.812500	34.000000
ABBOTTS BOOBY	0.714286	0.428571	0.535714	35.000000
ABYSSINIAN GROUND HORNBILL	0.823529	0.823529	0.823529	34.000000
AFRICAN CROWNED CRANE	0.928571	1.000000	0.962963	26.000000
AFRICAN EMERALD CUCKOO	0.962963	0.722222	0.825397	36.000000
...
YELLOW HEADED BLACKBIRD	0.900000	1.000000	0.947368	27.000000
ZEBRA DOVE	1.000000	0.967742	0.983607	31.000000
accuracy	0.872748	0.872748	0.872748	0.872748
macro avg	0.874869	0.874508	0.870849	16927.000000
weighted avg	0.878245	0.872748	0.871753	16927.000000

Figure 7: sample output of evaluation parameters for each element in the dataset.





Assessing Different Growing Media on Growth, Flowering and Yield of African Marigold (*Tegetes erecta* L.) under Low Hills of Uttarakhand

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ABSTRACT

Present field experiment was planned and conducted during 2021-22 at Horticulture Research “Assessing different growing media on growth, flowering and yield of marigold under low hills of Uttarakhand”. The experiment was laid out in randomized block design with three replications and nine treatments. The treatments comprised following levels of different organic growing media with different concentrations viz. T₁(control) T₂(Vermicompost+soil), T₃(FYM+soil), T₄(Cocopeat+soil), T₅(Leafcompost+soil), T₆(Cowurine+soil), T₇(Vermicompost+FYM+Cocopeat+soil), T₈(Block, School of Agriculture Sciences, SGRRU, Dehradun, Uttarakhand to investigate the Vermicompost+FYM+Cow Urine+soil), T₉(Vermicompost+FYM+Leafcompost+soil) and T₁₀(Vermicompost+FYM+LeafCompost+CowUrine+CocoPeat+Soil). The sowing of african marigold cultivar “Pusa Basanti” was done on 31/03/2022 and final harvest at 28/08/2022. Observations on various attributes viz. growth, flowering, yield and economics were recorded at regular intervals. The results revealed that treatment T₁₀ (Vermicompost+FYM+LeafCompost+CowUrine+CocoPeat+Soil) was found to be most effective in terms of vegetative characters such as Plant height (103.03cm), Internodal length (11.17cm), Plant spread (70.31cm), Number of primary branches (35.77), Number of leaves (297.71), Stem diameter (2.22cm). Whereas, flowering characters such as Flower stalk length(10.84 cm), Flower stalk girth (9.93cm), Duration of flowering (71.22 days), Number of flowers (107.35), Number of florets(139.53), Average fresh weight (7.68gram), Average dry weight(3.18gram), Longevity of flowers(11.83 days) and yield attributes viz. yield per plant (558.81 gram), yield per hectare (145.56 q) and net profit (Rs 89,384) was maximum in T₉ (Vermi compost + FYM + Leaf compost + Soil) and maximum B: C ratio (1:6.69) was recorded in





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T₆(Cowurine+soil).

Keywords: Organic, growing media, vermicompost, cowurine, cocopeat

INTRODUCTION

Marigold (*Tegetes* sp.). It is also known as *Gendha* in Hindi and also known as 'friendship flower' in United States of America. It belongs to the family Asteraceae or Compositae and consist a chromosome number (2n = 24). Marigold is one of the most important annual flowers cultivated in India. It is widely popular amongst the flower dealers and gardeners because of the various positive features, such as – easy to cultivate and has wide adaptability, wide range of its shape, size and colour along with its good keeping quality. Attractive and brightly coloured flowers are the most valuable and economic part of the plant and is mostly used for making bouquets, religious offerings, exhibitions, decorations etc.[1]. Besides of being grown as an ornamental flower it also consists of medicinal properties and the essential oil of the flower contains antioxidants. Healing properties of *Tegetes* species have been implemented by folk medicine for centuries. Marigold is also commonly used in the poultry industry as a food additive to brighten the egg yolk and poultry skin [2,29]. Marigold is a native to India. The genus *Tegetes* is a genus containing about 50 species of annual or perennial herbaceous plant but only few of them are majorly important and are grown regularly. Some of the important *Tegetes* varieties are: African or American Marigold (*Tegetes erecta*): These plants are tall, erect-growing, they grow up to a three feet in height. The flowers are globular in shape and relatively large in size and can measure up to 5 inches across. African marigolds are good for bedding purposes, its flowers are yellow to orange in colour and it takes a longer time to flower. French Marigold (*Tegetes patula*): These marigold cultivars grow from 5 inches to 18 inches, have the flower's colours are yellow, red and orange and a bi-colour pattern of red and orange is also seen on the flowers and the size of the flowers is 2 inches across.

French marigold is ideal for edging the flower bed and also in mass planting. A report shows the anti-bacterial activity of different solvents of marigold flower against *Alcaligenes faecalis*, *Bacillus cereus*, *Campylobacter coli*, *Escherchia coli* etc. The flavonoid possesses antibacterial activity against all the tested strains [3,30]. The Flavonoid-Patulitrin is one of the potential elements for its anti-bacterial activity. In the report of anti microbial activity in 19 plants used in Colombian traditional medicine for cutaneous infections, were screened against *Neisseria gonorrhoeae* by disc susceptibility assay. In all 71% of the crude extracts exhibited antibacterial activity against the antibiotic susceptible NG strain GCI – 182. The *Tegetes erecta* flower parts showed maximum inhibitory action against NG strain [4,28]. Allelopathy is the ability of an organism to produce chemicals that are toxic to other organisms. *Tegetes* species roots release the chemical alpha-terthienyl, one of the most toxic naturally occurring compounds found to date. This compound is nematocidal, insecticidal, antiviral and cytotoxic.

The presence of alpha-terthienyl inhibits growth because of itself and also because *Tegetes* species are non-host plants even when they do not contain allelopathic compounds [5,31]. The roots of *Tegetes* species roots release a chemical named alpha-terthienyl, it is one of the most toxic naturally occurring chemical found. This compound is nematocidal, insecticidal, antiviral, and cytotoxic in nature. The presence of this compound inhibits the nematode eggs to hatch yet it is unclear that the compound produced by *Tegete species* exhibits allelopathic effect it may also be possible because marigold are a non host for the nematodes. The use of chemical fertilizer is increasing day by day for the sake of increasing production. By the excess use of chemical fertilizer, the fertility of soil and health also deteriorate. Therefore, the use of organic media is one of the alternative ways for enhancing production and improves soil health. They increase the organic matter in the soil, increase microbial activity, enables a soil to hold more water, also help to improve the drainage in clay soil, improve nutritional security and reduce many problems related to crop production, Organic matter increases plant nutrients in the soil. Organic Growing medias help in sustainable and economic food production as well as sustainable agriculture. There are specific cultivars for different period of year and no particular cultivar of a group is suitable for growing successfully throughout the year.





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Therefore, it is very important to select the suitable cultivar for growing in a particular season with the use of different Organic Growing medias. Keeping these aims in view, the present experiment “Assessing different growing media on growth, flowering, yield economics of Marigold (*Tegetes erecta* L.) under Low Hills of Uttarakhand” was conducted at Horticulture Research Block, School of Agricultural Sciences, Shri Guru Ram Rai University, PathriBagh, Dehradun, Uttarakhand, India.

MATERIALS AND METHOD

The field experiment was conducted at Horticulture Research Block, Department of Horticulture, School of Agricultural Sciences, Shri Guru Ram Rai University, Dehradun, Uttarakhand during the summer season of 2021–22. The experiment was laid out in Randomized Block Design (RBD) and replicated thrice. Total ten treatments were tried namely T1 (control@100% soil), T2 (Vermicompost+soil@3:1), T3 (FYM+soil @3:1), T4(Coco peat+soil@3:1), T5 (Leaf compost+soil@3:1) T6 (Cow urine+soil@20%:1), T7 (Vermicompost+FYM+Cocopeat+soil @1:1:1:1), T8 (Vermicompost+FYM+CowUrine+soil @1:1:20%:1), T9 (Vermicompost+FYM+Leaf compost+soil@1:1:1:1) and T10 (Vermicompost+FYM+Leafcompost+CowUrine+Coco peat+ soil@1:1:1:20%:1:1). 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 Marigold cultivar “PusaBasanti” was chosen for research purpose. Organic growing media were prepared by mixing different concentration of vermicompost, FYM,coco peat, cow urine and leaf compost with soil and filling them in 1.5kg polybags according to their treatment respectively. The nursery was prepared on 31 March 2022 and the seedlings were transplanted on 21 April 2022 in their respective polybags. 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 promoting parameters during whole of the cropping period at 30, 60, 90 days after transplanting and at final harvest. The obtained data were statistically analyzed with using standard statistical method as suggested by [6].

RESULT AND DISCUSSION

The various growth, flowering and yield attributes viz. plant height (cm), number of primary branches, plant spread(cm), stem diameter(cm), number of leaves per plant, internodal length(cm)flower yield per hectare (Kg/ha), flower yield per plant (Kg)were significantly influenced by different doses of organic growing media as compared to control during the course of investigation. The data presented in Table-2, 3, 4, 5 and 6 were showed that the significant improvement was noticed when applied different combinations of organic growing media as compared to control. The findings of the present investigation were recorded and are thoroughly discussed below:

Growth attributes

Plant height (cm)

The observation of plant height, recorded at 30, 60, 90 DAT and at Final harvest was presented in Table 2 and Fig.1 revealed significant differences among the treatments. At 30 days after transplanting the maximum plant height was recorded in treatment T₂ (45.52cm).However, significant differences were observed with treatmentsT₃ (40.78cm) and T₁ (38.84cm). The following treatments were at par viz. T₅ (36.17cm), T₁₀ (35.07cm), T₈ (33.32cm), T₇ (32.71cm), T₆ (32.62cm) and T₉(31.96 cm). The minimum plant height (31.11 cm) was recorded under the treatment T₄.In case of 60 days after transplanting the maximum plants height was obtained in treatments T₂ (54.90cm), which was at par with treatment T₁ (50.28cm) and T₃ (49.86cm). The significant difference was recorded with treatment T₁₀ (46.83cm), T₅ (46.19cm), T₈ (45.45cm), T₇ (43.25 cm), T₆ (42.92 cm) and T₉ (41.61 cm). The minimum plant height (41.19cm) was recorded under treatment T₄. At 90 days of transplanting the maximum height was obtained in the treatments T₁₀ (73.89 cm), which was at par with the treatment T₈ (71.55 cm) and T₂ (71.09 cm). The significant differences were recorded with the treatments T₉(70.64 cm), T₃ (69.63 cm), T₇ (69.06 cm),T₅ (69.07 cm),T₁ (68.57 cm) and T₆ (67.12 cm). The minimum plant height (65.07 cm) was recorded under treatment T₄.At final harvest, the plant height was



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maximum in T₁₀ (103.04cm) which was comparable with T₈ (98.42 cm) and T₉ (96.84cm). However, significant difference was observed with treatment T₇ (95.64cm), T₅ (93.92cm), T₆ (93.02cm), T₃ (92.55cm), T₂ (92.24) and T₁ (90.31cm) while, minimum plant height was obtained in the treatment T₄ (88.68cm).

Internodal length (cm)

The observation of internodal length was recorded at 30, 60, 90 DAT and at final harvest and the results were significantly differs among the treatments. At 30 days after transplanting, the highest internodal length of African marigold was recorded in treatment T₃ (2.46cm) and it was at par with T₂ (1.86cm) and T₄ (1.74cm). However, significant differences were observed with treatment T₅ (1.71cm), T₈ (1.55cm), T₉ (1.54cm), T₁₀ (1.45cm) and T₁ (1.37cm). The minimum number of leaves (1.36cm) was recorded under the treatment T₆. In case of 60 days after transplanting the maximum internodal length was obtained in treatment (6.26 cm) and it was at power with T₄ (5.27cm) and T₅ (5.09cm) however significant differences were observed with treatments T₂ (4.99cm) T₇ (4.09cm), T₈(4.07cm) T₁ (4.03cm) T₆(3.99cm) and T₁₀(3.96cm). The minimum internodal length was observed in T₉ (3.95cm). In case of 90 days after transplanting the maximum internodal length was observed in T₃ (9.72cm) which was at par T₄(8.47cm), T₅(7.89cm), T₂(7.75cm). The significance differences were observed with treatment T₁(6.28cm) T₆(6.17cm) T₇(6.16cm) T₈ (6.04cm) and T₉(5.85cm). The minimum internodal length (5.77cm) was recorded under the treatment T₁₀. At the final harvest day after transplanting the maximum internodal length was observed in T₃(12.6cm), which was at par T₄(11.17cm). The significance difference was observed with treatments T₅(10.85cm), T₂ (10.36cm), T₉(10.23cm), T₁₀(9.95 cm), T₇(9.57cm), T₆(9.55cm), T₈(9.44cm). The minimum internodal length was observed in T₁(8.42cm) which is presented on Table 2 and shown in Fig. 2.

Plant spread (cm)

The observation of internodal length was recorded at 30, 60, 90 DAT and at final harvest and the results were significantly differs among the treatments. At 30 days after transplanting, the highest plant spread was recorded in treatment T₁₀ (30.78cm) and it was at par with T₄ (24.64cm) and T₃ (24.39cm). However, significant differences were observed with treatment T₅ (23.62cm), T₆ (21.20cm), T₈ (21.01cm), T₉ (18.06cm), T₂ (16.06cm) and T₁ (15.70cm). The minimum plant spread (13.53cm) was recorded under the treatment T₇. In case of 60 days after transplanting the maximum plant spread was obtained in treatment T₁₀(41.23cm) and it was at par with T₃ (33.95 cm) and T₄ (33.63cm) however significant differences were observed with treatments T₅ (32.36cm) T₆ (30.27 cm), T₈(29.58cm) T₉ (26.76cm) T₂(25.39cm) and T₁(24.72cm). The minimum plant spread was observed in T₇ (22.46cm). In case of 90 days after transplanting the maximum plant spread was observed in T₁₀(57.38cm) which was at par T₄(46.29cm), T₃(44.91cm), T₅ (44.83cm). The significance differences were observed with treatment T₈(44.76 cm), T₆(41.74cm), T₉(39.14cm), T₂(38.87cm) and T₁(35.04cm). The minimum plant spread (34.07cm) was recorded under the treatment T₇. At the final harvest day after transplanting the maximum plant spread was observed in T₁₀ (70.31cm), which was at par T₄ (61.57cm). The significance difference was observed with treatments T₅ (59.63cm), T₁₀ (59.54cm), T₃ (59.40 cm), T₆ (55.52cm), T₉ (52.38cm), T₂ (51.37cm), T₁ (46.60cm). The minimum internodal length was observed in T₇ (45.31cm) which is presented on Table 2 and shown in Fig. 3.

Primary branches

The observation of primary branches was recorded at 30, 60, 90 DAT and at final harvest and the results were significantly differs among the treatments. At 30 days after transplanting, the highest number of primary branches was recorded in treatment T₂ (15.80) and it was at par with T₃ (14.16) and T₁ (13.15). However, significant differences were observed with treatment T₅ (12.56), T₁₀ (12.17), T₈ (11.57), T₉ (11.42), T₇ (11.36) and T₆ (11.32). The minimum number of primary branches (10.80) was recorded under the treatment T₄. In case of 60 days after transplanting the maximum number of primary branches was obtained in treatment T₂(19.06) and it was at par with T₁ (17.46) and T₃ (17.31). However significant differences were observed with treatments T₁₉ (16.26), T₅ (15.99), T₈(15.79), T₇ (15.02), T₂ (25.390) and T₆(14.30). The minimum number of primary branches was observed in T₉ (14.44). In case of 90 days after transplanting the maximum number of primary branches was observed in T₁₀ (25.66) which was at par T₈(24.84), T₂(24.68) and T₉(24.56). The significance difference were observed with treatment T₃(24.18), T₅(23.96), T₇(23.98), T₁(23.80) and T₆(23.30). The minimum number of primary branches was (22.59) was recorded under the treatment



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T₄. At the final harvest day after transplanting the maximum number of primary branches was observed in T₁₀(35.77) which was at par T₈(34.17). The significance difference was observed with treatments T₉(33.63), T₇ (33.21), T₅(32.61), T₆(32.29), T₃(32.14), T₂(32.03), T₁(31.01). The minimum number of primary branches was observed in T₄(30.79) which is presented on Table 3 and shown in Fig. 4.

Number of Leaves

The observation of number of leaves per plant was recorded at 30, 60, 90 DAT and at final harvest and the results shows significant differences between the treatments. At 30 days after transplanting the highest value of number of leaves was recorded in treatment T₂ (126.19) and the lowest value (98.85) in the treatment T₉. At 60 days after transplanting, the maximum number of leaves was obtained in treatments T₂ (159.48) which were at par with the treatments T₃ (154.23) and T₁₀ (151.42). The significant difference was observed with treatment T₈ (147.03), T₅ (142.87), T₇ (139.83), T₆ (138.76), T₉ (134.52) and T₁ (133.18). The minimum number of leaves per plant (130.73) was recorded under the treatment T₄. In case of 90 days after transplanting, the maximum number of leaves was obtained in treatments T₉ (200.08) which were at par with the treatments T₁₀ (199.08) and T₈ (189.30). The significant difference was observed with treatment T₆ (180.28), T₇ (178.95), T₂ (161.78), T₃ (158.44), T₅ (157.06) and T₁ (153.34). The minimum number of leaves (147.937) was recorded under the treatment T₄. At final harvest days after transplanting, the number of leaves was maximum in T₁₀ (297.71) which was comparable with T₉ (247.54) and T₈ (239.96). However, significant difference was observed with treatment T₆ (231.36), T₇ (226.83), T₅ (213.36), T₃ (210.13) and T₂ (209.91). While, minimum number of leaves was obtained in the treatment T₁ (202.19) which is presented on Table 3 and shown in Fig. 5. Perhaps, the food formation was fast and more during initial stages, which might have resulted in better growth. The results of present findings are also corroborated by earlier workers [7,8,27].

Stem diameter (cm)

The observation of stem diameter was recorded at 30, 60, 90 DAT and at final harvest and the results shows significant differences between the treatments. At 30 days after transplanting the highest value of stem diameter was recorded in treatment T₉ (0.61cm) and the lowest value (0.45cm) in T₄. In case of 60 days after transplanting, the maximum stem diameter was obtained in treatments T₁₀ (1.22cm) which were at par with the treatments T₈ (1.21cm) and T₉ (1.18). The significant differences were observed with treatments T₂ (1.15cm), T₇ (1.14cm), T₁ (1.07cm), T₃ (1.04cm), T₅ (0.97cm) and T₄ (0.913 cm). The minimum stem diameter (0.87cm) was recorded under the treatment T₅. In case of 90 days after transplanting, the maximum stem diameter was obtained in treatments T₁₀ (2.0 cm), which were at par with the treatments T₂ (1.92cm) and T₇ (1.92cm). The significant differences were observed with treatments T₉ (1.92cm), T₈ (1.89cm), T₃ (1.87cm), T₅ (1.86cm), T₁ (1.84cm) and T₆ (1.80cm). The minimum stem diameter (1.73cm) was recorded under the treatment T₄. At final harvest days after transplanting, the stem diameter was maximum in T₁₀ (2.21cm) which was comparable with T₉ (2.21cm) and T₂ (2.10cm) however, significant difference was observed with treatment T₅ (2.09cm), T₆ (2.07cm), T₈ (2.07 cm), T₃ (2.06cm) and T₄ (2.01 cm). While, minimum stem diameter was obtained in the treatment T₁ (1.94 cm) which is presented on Table 3 and shown in Fig. 6. The better performance of growth attributes might be due to the sufficient amount of water in the growing media which might have increased various physiological processes, better plant nutrient uptake, higher rates of photosynthesis, which might reflect on increase in plant height, intermodal length, plant spread, number of primary branches, number of leaves and stem diameter. Similar findings were also reported by [9, 10,26].

Flowering attributes**Flower stalk length (cm)**

Different organic growing media treatments were found significant to achieve the flower stalk length. The treatment T₁₀ was significantly superior over the rest other treatments in respect to flower stalk length with length of (10.84 cm) which was at par with T₉ (10.12 cm) and minimum stalk length was recorded in T₆ (9.76 cm).

Flower stalk girth (mm)

The results in table 3 shows that the treatment T₁₀ was significantly superior over others in respect to flower stalk girth (9.93 mm) which was at par with T₉ (9.46 mm) and minimum in T₈ (8.70 mm).



**Number of days taken for first flower**

The number of days taken for first flower varied between 64.11 to 91.25. The highest number of days taken for first flowering was recorded in T₄ (91.25) and the minimum by T₆ (64.11). The significance difference were reported in T₁ (88.68), T₅ (85.01), T₂ (83.42), T₈ (82.41), T₃ (75.67), T₉ (74.80), T₁₀ (67.01) and T₇ (66.54). The combined influence of growing media improve drainage, aeration, lower compactness along with Leaf mould and Vermicompost bring down the pH to optimum level for availability of macro and micro nutrient uptake by plant root system which help to improve water holding capacity and higher photosynthetic activity result in better C:N ratio. When C:N ratio improve, simultaneously florigen plant hormone level also improves, which is responsible for earliest flower bud initiation, flower bud show colour. It might be due to the vigorous growth of the plant growing in the media and the rapid uptake of nutrient and water has a pronouns effect on production [11,12,13].

Duration of flowering

The duration of flowering varied between 71.22 to 51.45 days. The highest flowering duration was recorded in T₁₀ (71.22) and the minimum in T₂ (51.46). The significance difference were recorded in T₈ (67.44), T₉ (66.29), T₆ (64.45), T₇ (55.83), T₅ (55.77), T₃ (54.96), T₄ (54.76) and T₁ (52.18).

Number of flowers per plant

Data depicted in table 4 clearly reveals that the number of flowers per plant of all the treatments under study differs significantly and ranged from 36.21 to 107.35. The maximum number of flowers were noted in the treatment T₁₀ (107.35), which was found statistically at par with rest of the treatments. Further, minimum number of leaves was recorded in the treatment T₁ (36.21). Increased number of flower is attributed to the production of large number of flower buds along with the fact that termination of vertical growth by pinching lead to more laterals or secondary branches at early stage of growth, which then had sufficient time to accumulate carbohydrates for proper flower bud differentiation producing a greater number of flowers per plant [10-11]. Similar results were also reported by [14,15, 24] in marigold.

Number of florets

It is clear from the table 4 and Fig 5 that the number of florets of different treatments differed significantly and range from 139.53 to 58.56. The maximum number of florets was noted in the treatment T₁₀ (139.53). However significant differences were observed with rest of the treatments. The minimum number of florets (58.56) was recorded in treatment T₁.

Average fresh weight (g)

The fresh weight of flowers varied significantly from 2.40g (T₂) to 7.68g (T₁₀). The maximum average fresh weight was noted in the treatment T₁₀. Reason of maximum fresh weight of flower might be due to more availability of nutrients, media and genetic makeup. Similar findings have been reported by [16,17, 25].

Average Dry weight (g)

The dry weight of flowers varied significantly from 0.830g (T₂) to 3.69g (T₈). The maximum average dry weight was noted in the treatment T₈.

Shelf life (Days)

The longevity of flowers varied significantly from 3.57 (T₁) to 11.83(T₁₀). The maximum longevity was noted in the treatment T₁₀. That performance was influenced by the forms of different organic growing media. The increase in flower longevity might be due to the fact that organic substrate contains optimum levels of essential nutrients that produces quality flowers giving superior longevity of flowers on plant. Similar findings recorded by [18,19,20].





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Yield attributes

Flower yield (g/plant)

The data regarding the yield of harvested flowers differed significantly due to various treatments and are presented in table 5. The yield of flowers varied significantly from 140.37g (T₁) to 558.81g (T₁₀). The maximum yield of flowers was noted in the treatment T₁₀. Similar results were also recorded by [21,22,].

Flower yield (q/ha)

The yield of flowers varied significantly from 43.44q/ha (T₁) to 145.56 q/ha (T₁₀). The maximum yield of flowers was noted in the treatment T₁₀ and minimum in control. Similar results were also recorded by [23].

Economics

The economics of all the treatments were given in table 6. The net profit per hectare ranges from Rs.25,197 to 89,384. The maximum net profit per hectare was recorded under the treatment T₉ (Rs 89,384). While minimum net profit per hectare was obtained in the treatment T₂ (Rs.25,197).

The benefit cost ratio ranged from 1:1.68 to 1:6.69 depending on different treatments. It was found to be highest (1:6.69) under the treatments T₆ (Cow Urine + soil) and lowest (1:1.68) under the treatment T₁₀ (Vermi compost + FYM + Leaf compost + Cow urine + Coco peat + Soil) [24,32].

CONCLUSION

On the basis of present experimental research on “Assessing different growing media on growth, flowering and yield of African Marigold under Low Hills of Uttarakhand” in cultivar PusaBasanti, it can be concluded that among different organic growing media treatments, the combination of (Vermicompost + FYM + Leaf compost + Cow urine + Coco peat + Soil) i.e. T₁₀ was found to be most effective for increasing height of plant, number of leaves per plant, diameter of main stem, number of primary branches, plant spread, internodal length, flower stalk length, flower stalk girth, number of days taken to appearance of first flower, duration of flowering, number of flowers per plant, average fresh and dry weight of flowers, diameter of flower, longevity, yield per plant and yield (q/ha). Whereas economics of African marigold was recorded highest in T₆.

REFERENCES

1. Raghava S and Saxena V. Marigold. A potential commercial flower. Commercial flower production. Ed. IARI, New Delhi. 2011;8-16.
2. Chauhan S, Singh CN and Singh, AK. Effect of Vermicompost and pinching on growth and flowering in marigold cv. PusaNarangainda. Prog. Hortic. 2015;37(2):419.
3. Naik PV, Seetaramu GK, Patil GM, Tejaswini, Sadanand GK and Shivashankara KS. A study on evaluation of marigold genotypes for growth parameters under upper Krishna project command area in Karnataka state. International Journal of Chemical Studies. 2019;7(4):1562- 1566.
4. Srivastava SK, Singh HK and Srivastava AK. Spacing and pinching as factors for regulating flowering in marigold cv. PusaBasantiGaiinda. Haryana J Hortic. Sci. 2005, 34(1-2)
5. Meena Y, Sirohi HS, Tomar BS and Kumar S. Effect of planting time, spacing and pinching on growth and seed yield traits in African marigold (*Tagetes erecta*) cv. PusaNarangaiGaiinda. Indian Journal of Agricultural Sciences. 2015;85(6):797- 801.
6. Gomez K.A. and Gomez A.A. 1996. Statistical Procedures for Agricultural Research (2nd edition). John Willey and Sons, Inc. Singapore, pp. 139-240.
7. Garge VC, Malik S, Awasthi M, Singh SP, Chaudhary M and Kumar A. Effect of integrated nutrient management on flower quality of French Marigold (*Tagetes patula* L.) Cv.PusaArpita. International Research Journal of Pure and Applied Chemistry. 2020;21(24):154-156.
8. Gnyandev, B., Kurdikeri, M.B., Patil, A.A. and Channappagoudar B.B., 2014. Influence of pinching, nitrogen





Anshul Nautiyal et al.,

- level, and growth retardants spray on seed yield and quality of China aster cv. Phule Ganesh. International Journal of Tropical Agriculture, 32 (3-4), Pp. 377- 380.
9. Khanna PR, Bohra M, Punetha P and Nautiyal BP. Studies on the effect of organic manures and psb on vegetative and floral parameters of China aster (*Callistephus chinensis* (L.) Ness.) cv. Kamini under mid hills region of Himalaya. The Bioscan. 2016;11(4):2707-10.
 10. Khulbe A, Pandey S and Sah PS. 2013. Antidepressant like action of the hydromethanolic flower extract of *Tagetes erecta* mice and its possible mechanism of action. Indian Journal of Pharmacology, 45, 386–390.
 11. Bhusaraddi P., Bhagat V.V. and Kulkarni B.S. Evaluation of different French marigold (*Tagetes patula* L.) genotypes. The Pharma Innovation Journal. 2022; 11(2):2755-2759.
 12. Kumar V, Singh RS, Pal M, MD Ojha, AP Singh, RK Verma and PK Singh. Varietal performance of marigold (*Tagetes* spp.) under sub-tropical condition of Bihar. Journal of Pharmacognosy and Phytochemistry. 2020;9(3):922-924.
 13. Malik M, Kumar T, Jawla SK and Sahrawat A. Economic analysis of Marigold production under the different application of organic manures. The Pharma Innovation Journal. 2021;10(3):155-157.
 14. Mohanty, C. R., Mohanty, A. and Parhi R. 2015. Effect of planting dates on seed traits in African marigold cv. Sirakole. Agril. Science digest 35(4): 285-289.
 15. Nicholas M, 2013 COIR: Sustainable growing media . Practical hydroponics and greenw house. 138.
 16. Pare RK, Ram RA. 2013. Bio-enhancers: A potential tool to improve soil fertility, plant health in organic production of horticultural crops. Progressive Horticulture; 45(2):237-254.
 17. Parya C. Effect of integrated plant nutrient system for Gerbera flower production under protected cultivation. Journal of Applied Horticulture. 2017;19(2):139-142.
 18. Prakash, S., Anitha, P., Giridharan, M.P., Rajgopalan, A. and Rao, S.V.G., 2016. Impact of seasons and pinching on growth and flowering in African marigold. Journal of Tropical Agriculture, 54 (1), Pp. 50-54.
 19. Sasikumar K., Baskaran V. and Abirami K., 2015. Effect of pinching and growth retardants on growth and flowering in African marigold cv. PusaNarangiGaiinda. Journal of Horticultural Sciences, 10 (1), Pp. 109-111.
 20. Singh R., Meena M.L., Verma S., Mauriya S.K., Yadav S., Kumar V., Singh V., Kumar, L. and Maurya S.K., 2019. A Review on Effect of Pinching on Growth, Flowering, and Flower Yield of Marigold. Indian Journal of Pure Applied Bioscience, 7 (4), Pp. 493-501.
 21. Kanwar J, Khandelwal SK. Effect of plant growth regulators on growth and yield of African marigold (*Tagetes erecta* Linn.). Madras Agricultural Journal. 2013;100(1-3):45-47.
 22. Sudhagar R, Alexander R, Pamela EB and Kamalakannan S. Effect of integrated nutrient management on the flower yield of African Marigold (*Tagetes erecta* L.) cv Local Orange. International Journal of Emerging Technologies and innovative Research. 2019;6(5):284-289.
 23. Suvalaxmi Patel, A. K. Das, D. K. Dash. 2016. Effect of Plant Growth Regulators on Growth and Yield Attributes of African Marigold (*Tagetes erecta* L.), International Education & Res. J. 2(6):44-45.
 24. Dingrodiya P, Gupta NK, Bhadouriya RS, Ajay H. Effect of growing media on growth and flowering of cut roses under protected environmental condition. International Journals of Microbiology Research. 2017;9(2):861-863.
 25. Chauhan RV, Varu DK, Kava KP, Savaliya VM. Effect on different media on growth flowering and cut flower yield of gerbera under protected condition. The Asian Journal of Horticulture. 2014;9(1):228-231.
 26. Padhiyar BM, Bhatt DS, Desai KD, Patel VH, Chavda JR. Influence of different potting media on growth and flowering of pot Chrysanthemum varAjina purple. International Journal of Chemical Studies. 2017;5(4):1667-1669.
 27. Nowak J, Mynett K. The effect of growth regulators on post-harvest characteristics of cut Liliium 'Prima' inflorescences. Acta Horticulturae. 1985;167:109- 116.
 28. Sujatha A Nair, Singh V, Sharma TVRS. Effect of plant growth regulator on gerbera (*Gerbera jamesoni*) Indian J. Hort. 2002;60(2):192-194.
 29. Ikram S, Habib H, Khalid N. Effect of different pitting media combinations on growth and vase life of Tuberose (*Polianthes tuberosa* Linn.). Pakistan Journal of Agricultural Science. 2012;49(2):121-125.
 30. Shivakumar. Evaluation of African marigold (*Tagetes erecta* L.) Indian Journal of Ornamental Horticulture.





Anshul Nautiyal et al.,

2014;10:132-234.

31. Singh D, Singh AK. Characterization of African marigold (*Tagetes erecta* L.) genotypes using morphological characters. Journal of Ornamental Horticulture. 2006;9(1):40-42.
32. Meshram P, Badge S, Gaidhani A. Influence of Foliar Application of Gibberellic Acid and NAA on Growth Quality and Flower Yield in African Marigold. Journal of Agroecology and Natural Resource Management. 2015;2(2):162– 164.

Table:1 Treatment details

Treatment	Combinations	Concentration
T ₁	Control	Soil 100%
T ₂	Vermicompost + Soil	3 : 1
T ₃	FYM + Soil	3 : 1
T ₄	Cocopeat + Soil	3 : 1
T ₅	Leaf compost + Soil	3 : 1
T ₆	Cow urine + Soil	20 %: 1
T ₇	Vermicompost + FYM + cocopeat + Soil	1 : 1 : 1 : 1
T ₈	Vermicompost+ FYM + cow urine + Soil	1 : 1 : 20 %: 1
T ₉	Vermicompost + FYM + leaf compost + Soil	1 : 1 : 1 : 1
T ₁₀	Vermicompost + FYM + Cocopeat + cow urine + leaf compost + Soil	1 : 1 : 1 : 20% : 1 : 1

Table 2: Effect of various organic growing media on plant height, internodal length and plant spread at different harvest intervals

Treatment	PLANT HEIGHT (cm)					INTERNODAL LENGTH (cm)					PLANT SPREAD (cm)				
	30 D AT	60 D AT	90 D AT	AT FINAL HARVEST	ME AN	30 D AT	60 D AT	90 D AT	AT FINAL HARVEST	ME AN	30 D AT	60 D AT	90 D AT	AT FINAL HARVEST	ME AN
T ₁	38.84	50.28	68.56	90.31	62.00	1.36	4.03	6.27	8.42	5.03	15.70	24.72	35.03	46.60	30.51
T ₂	45.51	54.90	71.09	92.24	65.94	1.86	4.99	7.75	10.36	6.24	16.05	25.39	38.87	51.37	32.92
T ₃	40.78	49.86	69.62	92.55	63.21	2.46	6.26	9.72	12.62	7.77	24.39	33.94	44.91	59.40	40.66
T ₄	31.11	41.18	65.06	88.68	56.51	1.74	5.27	8.47	11.16	6.66	24.63	33.63	46.29	61.57	41.53
T ₅	36.16	46.19	69.01	93.92	61.32	1.70	5.08	7.89	10.85	6.38	23.62	32.35	44.83	59.62	40.11
T ₆	32.62	42.91	67.12	93.02	58.92	1.36	3.98	6.17	9.55	5.27	21.20	30.26	41.74	55.52	37.18
T ₇	32.71	43.25	69.06	95.63	60.16	1.53	4.09	6.15	9.57	5.34	13.53	22.46	34.07	45.31	28.84
T ₈	33.32	45.47	71.54	98.41	62.19	1.55	4.06	6.04	9.43	5.27	21.00	29.58	44.76	59.54	38.72
T ₉	31.95	41.60	70.63	96.84	60.26	1.54	3.95	5.85	10.23	5.39	18.06	26.76	39.14	52.38	34.09
T ₁₀	35.06	46.83	73.89	103.03	64.71	1.45	3.96	5.77	9.95	5.29	30.78	41.23	57.38	70.31	49.93
CD (5%)	4.88					0.76					2.05				





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SE (m)	1.67	0.26	0.70
SE (d)	2.36	0.37	0.99
C.V. (%)	5.43	8.95	3.75

Table 3: Effect of various organic growing media on primary branches, number of leaves and stem diameter at different harvest intervals

Treatment	PRIMARY BRANCHES					NUMBER OF LEAVES					STEM DIAMETER (cm)				
	30 D AT	60 D AT	90 D AT	AT FINAL HARVEST	MEAN	30 DAT	60 DAT	90 DAT	AT FINAL HARVEST	MEAN	30 D AT	60 D AT	90 D AT	AT FINAL HARVEST	MEAN
T1	13.15	17.46	23.80	31.01	21.36	105.26	133.18	153.34	202.19	148.49	0.54	1.07	1.84	1.94	1.35
T2	15.80	19.06	24.68	32.03	22.89	126.19	159.48	161.78	209.91	164.34	0.58	1.15	1.92	2.10	1.44
T3	14.16	17.31	24.17	32.14	21.95	125.28	154.23	158.44	210.13	162.02	0.57	1.04	1.87	2.06	1.39
T4	10.80	14.30	22.59	30.79	19.62	99.13	130.73	147.93	200.80	144.65	0.45	0.91	1.73	2.00	1.28
T5	12.56	15.99	23.96	32.61	21.28	111.35	142.87	157.06	213.73	156.25	0.49	0.97	1.86	2.09	1.36
T6	11.32	14.83	23.30	32.29	20.44	100.92	138.75	180.28	231.36	162.83	0.44	0.87	1.80	2.07	1.30
T7	11.35	15.02	23.98	33.21	20.89	101.17	139.83	178.94	226.83	161.70	0.58	1.13	1.92	2.05	1.42
T8	11.57	15.79	24.84	34.17	21.59	103.07	147.03	189.30	239.96	169.84	0.57	1.20	1.89	2.07	1.44
T9	11.41	14.44	24.56	33.62	21.01	98.84	134.51	200.07	247.54	170.24	0.61	1.18	1.92	2.11	1.46
T10	12.17	16.26	25.65	35.77	22.47	108.47	151.41	199.08	297.71	189.17	0.61	1.22	2.01	2.21	1.51
CD (5%)	1.70					3.92					0.07				
SE (m)	0.58					1.20					0.03				
SE (d)	0.82					1.59					0.04				
C.V. (%)	2.45					3.07					3.66				

Table 4: Effect of various organic growing media on flower stalk length, flower stalk girth, number of days for first flower, Duration of flowering, Number of Flowers per plant, Number of florets, Average fresh weight (g), Average dry weight (g) and shelf life of flowers per hectare at final harvest interval

Treatment	Flower stalk length (cm)	Flower stalk girth (mm)	Number of days for first flower	Duration of flowering (Days)	Number of Flowers per plant	Number of florets	Average fresh weight (g)	Average dry weight (g)	Shelf life (days)
T ₁	7.31	5.73	88.68	52.18	36.21	58.56	2.77	0.95	3.57





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T ₂	8.44	6.07	83.42	51.46	45.38	64.68	2.40	0.83	4.66
T ₃	8.67	5.93	75.67	54.96	47.61	80.05	3.54	1.57	4.02
T ₄	9.45	6.00	91.25	54.76	49.47	92.31	4.40	1.99	5.17
T ₅	8.70	6.87	85.01	55.77	52.59	72.19	4.09	1.72	7.07
T ₆	9.76	7.10	64.11	64.45	65.19	93.97	4.93	2.21	9.44
T ₇	8.38	7.30	66.54	55.83	86.60	80.87	6.63	3.29	9.52
T ₈	9.69	8.70	82.41	67.44	89.15	95.56	7.62	3.69	10.78
T ₉	10.12	9.47	74.80	66.29	95.40	107.16	7.12	3.57	10.82
T ₁₀	10.84	9.93	67.01	71.22	107.35	139.53	7.68	3.18	11.83
C.D. 5%	1.40	0.67	4.75	5.04	5.67	10.68	1.03	0.59	1.11
SE(m)	0.47	0.22	1.59	1.68	1.89	3.57	0.34	0.20	0.37
SE(D)	0.66	0.32	2.24	2.38	2.68	5.05	0.49	0.28	0.53
C.V	8.86	5.33	3.53	4.90	4.86	6.98	11.68	15.04	8.39

Table 5: Effect of various organic growing media on yield of flowers per plant and yield of flowers per hectare

Treatment	Yield of flowers per plant (g)	Yield of flowers per hectare (q)
T ₁	140.37	43.44
T ₂	169.14	53.18
T ₃	206.22	57.16
T ₄	219.77	67.08
T ₅	257.63	76.49
T ₆	332.33	83.97
T ₇	397.28	90.95
T ₈	361.34	101.40
T ₉	439.27	106.01
T ₁₀	558.81	145.56
C.D. 5%	36.53	10.79
SE(m)	12.20	3.60
SE(D)	17.25	5.09
C.V	6.85	7.56





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Table 6: Economic of African marigold cultivation under the influence of different organic growing media

Treatment	Net return(Rs ha ⁻¹)	B:C ratio
T ₁	43283.52	1 : 2.44
T ₂	25,197	1 : 0.91
T ₃	51,327	1 : 10.12
T ₄	38264	1 : 0.88
T ₅	61,028	1 : 5.02
T ₆	71,174	1 : 6.69
T ₇	39,441	1 : 1.77
T ₈	85,761	1 : 6.60
T ₉	89,384	1 : 6.52
T ₁₀	84,631	1 : 1.68

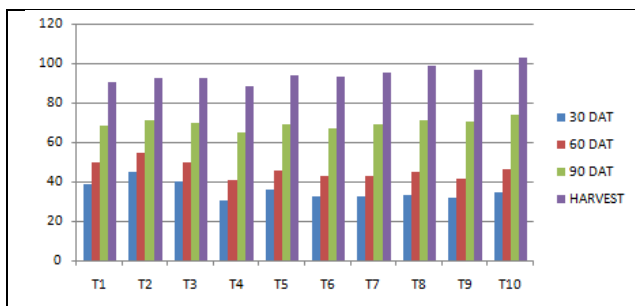


Fig 1: The effect of various organic growing media on plant height (cm) at different harvest interval on African marigold

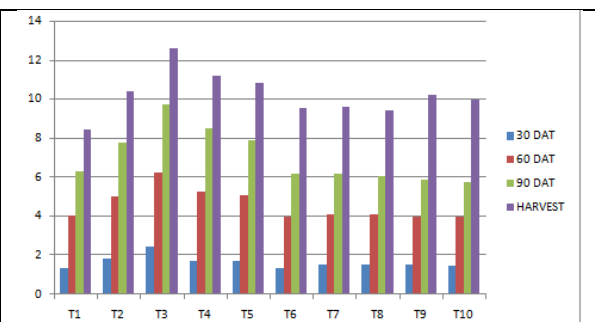


Fig 2: The effect of various organic growing media on internodal length (cm) at different harvest interval on African marigold

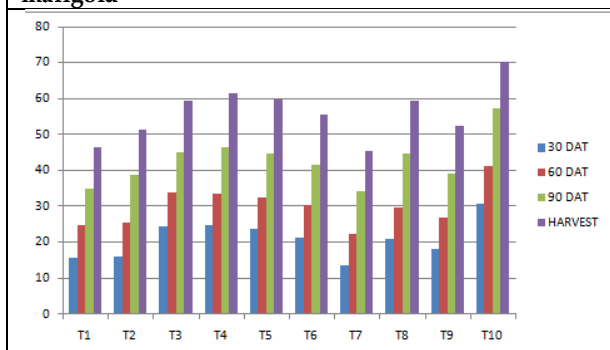


Fig 3: The effect of various organic growing media on plant spread (cm) at different harvest interval on African marigold

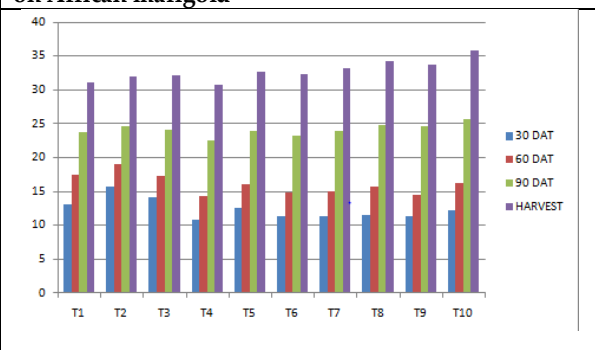
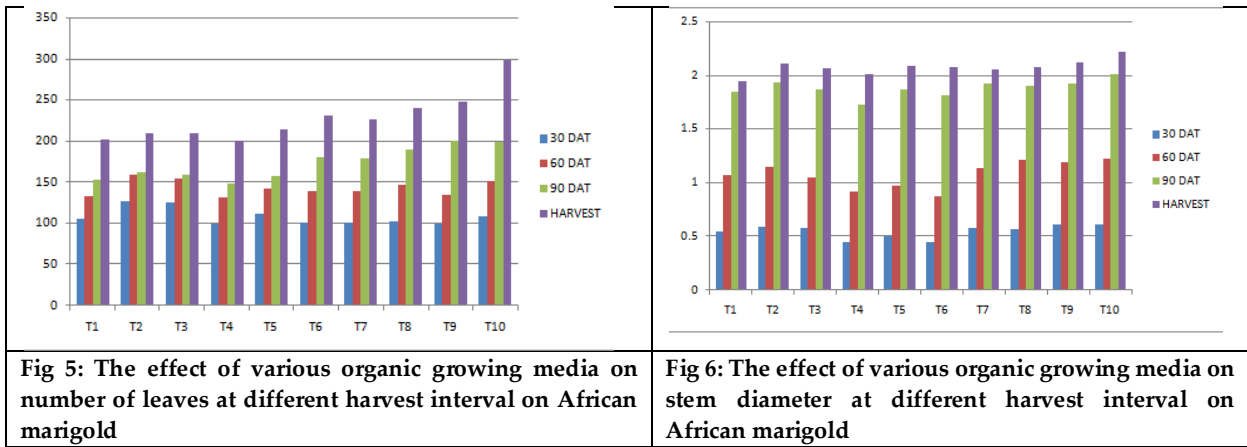


Fig 4: The effect of various organic growing media on primary branches at different harvest interval on African marigold





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Powder Face Scrub Formulation with Antioxidant Attributes

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ABSTRACT

This work was carried out to develop a powder face scrub formulation that is suitable for storage in environmentally friendly containers. Further, the formulation was functionalized by augmenting antioxidant activity. The surfactant used in the formulation was PEG 150-distearate. The principle abrasive attribute was achieved by incorporation of walnut shell powder and *Hemidesmus indicus* root powder. Rutin and *Albizia amara* leaf powder were incorporated to render the formulation capable of exhibiting antioxidant activity. The scrubbing effect of the formulations was qualitatively tested employing the agar surface scratching protocol. When tested for scrubbing action, the formulation described herein was found to elicit appreciable effect in comparison to a commercial face scrub. Antioxidant attributes were tested *in vitro* employing the total antioxidant capacity and DPPH radical scavenging assays in addition to evaluation of total phenolic content. Incorporation of *Albizia amara* leaf powder significantly enhanced antioxidant activity without any impact on the scrubbing effect. Formulation containing walnut shell powder, *Hemidesmus indicus* root powder and *Albizia amara* leaf powder exhibited significant antioxidant activity while exhibiting strong scrubbing effect. Taken together, our data suggests that the formulation disclosed herein can be further explored as a viable formulation for use as face scrub. The formulation being powder in nature is suitable for storage in environmentally friendly containers, and therefore could be useful in minimizing use of plastic-based packing material for storage of face scrubs.



**Dilip et al.,****Keywords:** *Albizia amara* leaf powder, Face scrub, *Hemidesmus indicus* root powder, Antioxidant.

INTRODUCTION

Use of face scrub is a very popular practice for cleaning and exfoliation of skin. Despite well known adversity of plastic materials due non-degradability, they continued to be used as packaging material for cosmetics and cleansing formulations. This problem could be overcome by replacing liquid formulations of cosmetics and cleansing products with powder or dry formulations. In this regard, we have earlier developed a powder shampoo formulation with antioxidant attributes [1]. It is relatively straightforward to commercialize several cleansing products such as shampoo and face scrubs owing to the fact that the user could procure a powder formulation from the market and reconstitute it with water prior to use. Manufacturing of powder formulations can be achieved by simple physical blending of ingredients to homogeneity. Such powder formulations can be stored and sold in environmental friendly containers such those made of wood, recyclable metals and cardboard. Since many cosmetics and cleansing formulations remain in contact with skin for varied periods of time, it may be argued that it is beneficial to functionalize the formulations with antioxidant or anti-microbial attributes. Reactive oxygen species generated by various cellular mechanisms have the propensity to cause oxidative damage to cellular macromolecules if not checked by antioxidant defences[2]. Consequently, several investigators have attempted to develop cosmetic and cleansing formulations with antioxidant attributes[3–8]. This aim of the work presented by us herein was to develop a powder face scrub formulation that demonstrates significant antioxidant activity *in vitro*.

MATERIALS AND METHODS

Chemicals

Ammonium molybdate, ascorbic acid, disodium hydrogen phosphate, FC reagent, gallic acid, methanol, sodium carbonate, sodium benzoate and rutin were obtained from Sisco Research Laboratories (India). Carboxymethyl cellulose was obtained from Hi Media, India. PEG 150 stearate and walnut shell powder were from BRM Chemicals, India. Microcrystalline cellulose was from Accent Microcell Pvt Ltd, India. Mannitol and maltodextrin were procured from Bioven Ingredients Pvt Ltd, UP. *Hemidesmus indicus* root and *Albizia amara* leaves were procured from local market. All other chemicals used in the present study were of analytical grade.

Face scrub composition

Face scrub composition was prepared by mixing PEG 150 stearate, Microcrystalline cellulose, Mannitol, *Hemidesmus indicus* root powder, *Albizia amara* leaf powder, Walnut shell powder, Carboxymethyl cellulose, Rutin, Sodium benzoate and Maltodextrin. The details regarding the composition are given in Table 1. Below described ingredients were mechanically blended to obtain a homogenous powder. For comparison of antioxidant potential, four different formulations were prepared 'FA', 'FB', 'FC', 'FD'.

Agar scratch assay

In brief, plates were prepared with 2.0 % agar containing a small pinch of coomassie brilliant blue dye. The dye was incorporated in to molten agar and the agar was poured on petridish and allowed to solidify. Dry formulations were wetted with water and placed on the centre of the plate and the surface of the agar was scrubbed with the help of index finger in 100 circular motions. For comparison, equal amount on commercially available scrub as well as a moisturizing cream without any scrubbing agent was tested.

Total phenolic content

Folin-Ciocalteu method was used for the estimation of the phenolic content in of the powder face scrub formulations. The phenolics in the extract reduces the reagent to produce molybdenum-tungsten blue which is read at 765nm, intensity of the colour produced was found to be in linear relationship with the concentration of phenolics. The





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experiment was carried out in a 96-well plate. The assay was initiated by with the addition of 85µl of distilled water followed by 10µl of sample (methanolic extract of powder face scrub) and 25µl of FC reagent (1:1 dilution). Post an incubation period of 6 minutes, 100µl Na₂CO₃ (75g/l) was added and plates were in dark for 90 min. The plates were read at 765nm using a microplate reader. Gallic acid was used as standard and results were expressed as gallic acid equivalents [9].

Total anti-oxidant activity

The total antioxidant capacity (TAC) of the formulation was spectroscopically determined using phosphomolybdenum method which is based on the reduction of Mo (VI) to Mo (V) complex under acidic conditions. 50µl of the methanolic extract of the formulation was mixed with 500µl of the reagent (28 mM sodium phosphate, 4mM ammonium molybdate and 0.6M sulphuric acid) and kept in boiling water bath for 90 mins. After cooling to room temperature, the absorbance was measured at 695nm. Ascorbic acid was used to obtain the calibration curve[10].

Radical scavenging activity

The radical scavenging activity exhibited by face scrub formulations was determined by monitoring scavenging of the free radical α , α -diphenyl- β -picrylhydrazyl (DPPH) spectrophotometrically. 100µl of DPPH reagent (8mg in 100 ml methanol) was incubated along with 100µl of sample in 96 well plate for 30 min in dark and read at 514nm¹¹.

Statistical analysis

Data have been represented as mean \pm SD (n=3). ANOVA and Tukey post hoc tests were determined to determine the significance in differences of means.

RESULTS

Fig. 1 shows impact of scrubbing the agar surface with the above-mentioned substances. While application of moisturizer did not elicit any scratching of the agar surface (Fig 1, A), commercial face scrub used as obtained from the tube resulted in significant scratching on agar surface (Fig 1, B). Formulation 'FA', containing walnut shell powder and rutin resulted in observable scratching of agar surface (Fig 1, FA). While formulation FC, containing *Albizia amara* leaf powder did not elicit appreciable scratching (Fig 1, FC), formulation FB (*Hemidesmus indicus* root powder and rutin) and formulation FD (Walnut shell powder, *Albizia* leaf powder, *Hemidesmus indicus* root powder and rutin) both elicited observable scratching on the agar surface. Data from antioxidant assays are depicted in Fig 2. As depicted in Fig 2A, among the tested formulations, 'FD' possessed highest phenolic content. Phenolic content in formulations 'FA' and FB were lower compared to that of 'FC' and 'FD'. DPPH radical scavenging activity of formulations 'FA' and FB were lower compared to that of 'FC' and 'FD'. FD, despite lacking statistical significance when compared to 'FC', possessed slightly higher radical scavenging efficacy (Fig. 2B). Total antioxidant capacity of formulations is depicted in Fig. 2C. Total antioxidant capacity of formulations 'FA' and FB were lower compared to that of 'FC' and 'FD'. Addition of *Albizia* leaf caused significant increase in the total antioxidant capacity (Fig. 2C).

DISCUSSION

This work focused on development of a powder face scrub formulation that can be stored and sold in environmental friendly material as wood or metal containers. Most cosmetics sold in the market place are stored and sold in plastic containers due to the fact that they are formulated in the liquid or liquid concentrate formats. Products formulated in dry or powder formats are highly suitable for storage, transportation and sales in environmental friendly material as wood or metal containers. Further, formulations developed in powder format also offer the advantage of ease of manufacturing as well as improved logistics in transportation due to reduced volumes. Keeping above in mind, we developed a face scrub in powder formulation. The face scrub contained walnut shell powder as the principle abrasive agent. Formulation 'FD' listed in the Table 1 represents the complete formulation while 'FA', 'FB' and 'FC'



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were developed to generate a comparative picture of effect of ingredients on scrubbing activity and antioxidant attributes. Walnut shell powder was used as the scrubbing agent in formulations 'FA', 'FC' and 'FD'. Formulation FD was strengthened with Hemidesmus root powder, which exhibited mild scrubbing effect per se (FB). It is desirable to incorporate anticaking agents to prevent lump formation and maintain flow characteristics. In order to achieve this, microcrystalline cellulose and Mannitol were incorporated in to the formulation. We used PEG 150 stearate as the surfactant. Use of a surfactant will render the formulation capable of removing grease and dirt. The product is designed to be reconstituted in water by the user. When reconstituted, it is desirable to have the product in a gel like consistency. In order to achieve this, carboxymethyl cellulose was incorporated as a gelling agent. Maltodextrin was used a filler to make up the formulation to a final weight of 100 grams. Plants are a rich source of antioxidant activity. Phenolics are among the chief groups of antioxidant molecules present in plants^[12]. Rutin, a member of the flavonoid group, is a glucoside of quercetin. Widely distributed in plants, rutin is known for antioxidant, anti-inflammatory and anti-diabetic effects^[13–18]. We observed that incorporation of Albizia leaf powder was associated significant increase in total phenolic content of the formulations (FC and FD). Interestingly, antioxidant activity of Albizia amara leaves has been reported earlier¹⁹. DPPH radical scavenging activity and assessment of total antioxidant activity are popular methods for in vitro assessment of antioxidant activity. Incorporation of Albizia leaf powder into the formulation resulted in significant increase in radical scavenging and total antioxidant activity of the formulation (FC and FD). The complete formulation (FD) represents a formulation that exhibits appreciable abrasive effect due incorporation of walnut shell powder and Hemidesmus root powder. Further, addition of rutin and Albizia amara leaf powder contributes to antioxidant attributes. Taken together, our formulation provides a face scrub in powder format with antioxidant activity.

CONCLUSION

The paper discloses proof-of-concept for a powder face scrub formulation with antioxidant attributes. We believe that the formulation can be further tested for safety. If commercialized, the powder formulation described herein could reduce the use of plastic as packaging material.

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Conflict of Interest

None

REFERENCES

1. Madhavan, A. *et al.* Powder shampoo formulation with antioxidant activity: in vitro perspectives. *Arab Gulf J. Sci. Res.* **ahead-of-print**, (2023).
2. Bandyopadhyay, U., Das, D. & Banerjee, R. K. Reactive oxygen species: Oxidative damage and pathogenesis. *Curr. Sci.* **77**, 658–666 (1999).
3. Bakr, R. O., Amer, R. I., Fayed, M. A. A. & Ragab, T. I. M. A Completely Polyherbal Conditioning and Antioxidant Shampoo: A Phytochemical Study and Pharmaceutical Evaluation. *J. Pharm. Bioallied Sci.* **11**, 105 (2019).
4. Anzai, A., Pereira, A. F., Malaquias, K. R., Guerra, L. O. & Mercuri, M. Efficacy and safety of a new formulation kit (shampoo + lotion) containing anti-inflammatory and antioxidant agents to treat hair loss. *Dermatol. Ther.* **33**, e13293 (2020).
5. Panontin, J. F., Rambo, M. K. D., Isaac, V., Seibert, C. S. & Scapin, E. New antioxidant lauryl-free herbal shampoo formulation with a Brazilian plant extract. *Brazilian J. Biol.* **82**, e264677 (2022).
6. Salem, Y. *et al.* Exhausted Grape Seed Residues as a Valuable Source of Antioxidant Molecules for the





Dilip et al.,

- Formulation of Biocompatible Cosmetic Scrubs. *Mol.* 2023, Vol. 28, Page 5049 **28**, 5049 (2023).
7. Ayyappadasan, G., Rubavathi, S. & Kanimozi, S. Formulation and Evaluation of Polyherbal-Spirulina Based Conditioning and Antioxidant Shampoo. *Res. J. Pharm. Technol.* **16**, 2317–2321 (2023).
 8. Hilda, D., Arini, A. & Nancy, C. D. Formulation of Body Scrub Cream From Extract of Arabika Green Coffee (*Coffea arabica* L.) as Antioxidant. *Proc. 4th Int. Conf. Sustain. Innov. 2020–Health Sci. Nurs. (ICoSIHSN 2020)* **33**, 337–342 (2021).
 9. Herald, T. J., Gadgil, P. & Tilley, M. High-throughput micro plate assays for screening flavonoid content and DPPH-scavenging activity in sorghum bran and flour. *J. Sci. Food Agric.* **92**, 2326–2331 (2012).
 10. Alam, M. N., Bristi, N. J. & Rafiquzzaman, M. Review on in vivo and in vitro methods evaluation of antioxidant activity. *Saudi Pharm. J.* **21**, 143–152 (2013).
 11. Lee, K. J., Oh, Y. C., Cho, W. K. & Ma, J. Y. Antioxidant and Anti-Inflammatory Activity Determination of One Hundred Kinds of Pure Chemical Compounds Using Offline and Online Screening HPLC Assay. *Evidence-based Complement. Altern. Med.* **Article ID**, 165457 (2015).
 12. Amarowicz, R. & Pegg, R. B. Natural antioxidants of plant origin. *Adv. Food Nutr. Res.* **90**, 1–81 (2019).
 13. Guardia, T., Rotelli, A. E., Juarez, A. O. & Pelzer, L. E. Anti-inflammatory properties of plant flavonoids. Effects of rutin, quercetin and hesperidin on adjuvant arthritis in rat. *Farm.* **56**, 683–687 (2001).
 14. Yoo, H., Ku, S. K., Baek, Y. D. & Bae, J. S. Anti-inflammatory effects of rutin on HMGB1-induced inflammatory responses in vitro and in vivo. *Inflamm. Res.* **63**, 197–206 (2014).
 15. Kamalakkannan, N. & Prince, P. S. M. Rutin improves the antioxidant status in streptozotocin-induced diabetic rat tissues. *Mol. Cell. Biochem.* **293**, 211–219 (2006).
 16. Gao, L. et al. Hypoglycemic and hypolipidemic effects of rutin on hyperglycemic rats. *J. Tradit. Chinese Med. = Chung i tsa chih ying wen pan* **40**, 654–663 (2020).
 17. Yang, J., Guo, J. & Yuan, J. In vitro antioxidant properties of rutin. *LWT - Food Sci. Technol.* **41**, 1060–1066 (2008).
 18. Gullón, B., Lú-Chau, T. A., Moreira, M. T., Lema, J. M. & Eibes, G. Rutin: A review on extraction, identification and purification methods, biological activities and approaches to enhance its bioavailability. *Trends Food Sci. Technol.* **67**, 220–235 (2017).
 19. Rajkumar, T., Satheesh Kumar, E. & Sinha, B. Evaluation of antioxidant properties of Albizia Amara leaves. *Int. J. Adv. Pharm. Biol. Sci.* **2**, 99–106 (2012).

Table 1. Composition of powder face scrub formulations

Ingredients	Powder Formulations			
	FA	FB	FC	FD
PEG 150 Stearate	10	10	10	10
Microcrystalline cellulose	25	25	25	25
Mannitol	5	5	5	5
<i>Hemidesmus indicus</i> root powder	0	10	0	10
<i>Albizia amara</i> leaf powder	0	0	10	10
Walnut shell powder	15	0	0	15
Carboxymethyl cellulose	7.5	7.5	7.5	7.5
Rutin	0.5	0.5	0.5	0.5
Sodium benzoate	0.1	0.1	0.1	0.1
Maltodextrin	36.9	41.9	41.9	16.9



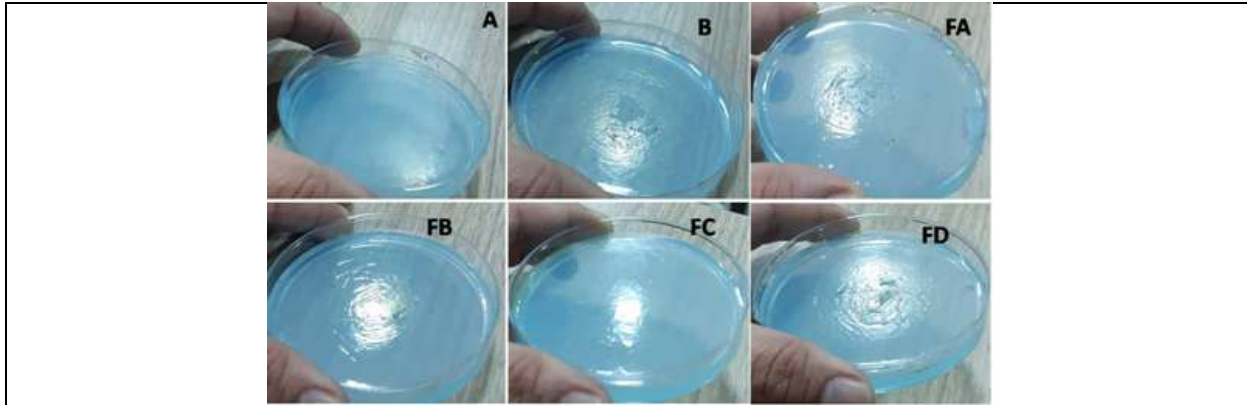


Fig. 1. Agar surface starching assay (A: Moisturizer; B; Commercially available face scrub, Composition of FA, FB, FC and FD are given in Table 1)

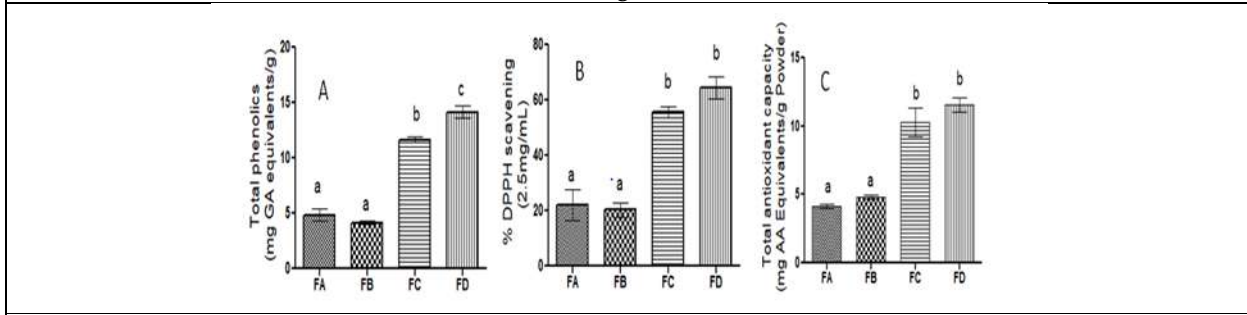


Fig 2. Total Phenolic content (A), DPPH radical scavenging activity (B) and Total antioxidant capacity (C) of face scrub formulations. Composition of FA, FB, FC and FD are given in Table 1. Data expressed as mean ± SD, n=3. Bars with different letters are significantly different, p<0.05 (ANOVA and Tukey Test).





Women Entrepreneurs and COVID-19: Challenges and Opportunities

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ABSTRACT

The pandemic has resulted in new solutions to rising technological challenges. Entrepreneurship has provided opportunities from the Medieval period to post-independence. This historical concept boomed during the pandemic period. Women's entrepreneurship has taken a crucial role in the global economy. Women entrepreneurs are essential in creating employment, group dynamics, communication, and economic flow. This paper mainly focuses on female entrepreneurs, the challenges faced during and post-Covid, and the opportunities identified (Borah et al. 2023).

Keywords: Women Entrepreneurship, Pandemic, Education, Innovation

INTRODUCTION

An entrepreneur is willing to take potential risks by default in establishing and operating his business to generate revenue for a more significant cause. The concept of entrepreneurship is a vast topic that began early in the form of a barter system to exchange goods and services for things with value. Entrepreneurship is the process of entrepreneurs having new ideas, products, or services and creating new businesses with opportunities by taking all the risks with available resources. According to the Indian government, a woman's entrepreneurship is "an Enterprise owned by and controlled by a woman with a minimum financial interest of 51% of capital and at least 51% of the employment generated in the enterprise to women". Women have contributed to economic growth as entrepreneurs for the past ten years. Through the concept of starting their own business irrespective of their objectives, they have been generating employment for individual purposes as well as other individuals while providing the



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necessary alternatives for the existing complexes in the society while exploring various potential business opportunities for their sustainability along with the growth of their entrepreneurship practices. Apart from all these possible outcomes, women are considered a smaller group of entrepreneurs, which is why they fail to have the taste of success. Women strive to sustain their businesses within the markets. Concerned authorities should define the policies, processes, laws, and regulations to yield and enhance the potential of women as a smaller group through which economic conditions also increase. "Empowering women is a prerequisite for creating a good nation; when women are empowered, a stable society is guaranteed. Women's empowerment is essential as their thoughts and value systems lead to developing a good family, society, and ultimately a good nation," stated Dr.APJ Abdul Kalam. Studies have shown that female entrepreneurship has attracted much attention, considering concrete evidence that it supports economic growth and development. Women entrepreneurs are still considered a minor part of the whole, so they are obligated to certain complex obstacles, contrasting with the challenges that men entrepreneurs encounter. With many opportunities, there is an integral development of women entrepreneurs in India. Ifemale entrepreneurs constitute 14% of the total number of entrepreneurship practices in India in the sixth economic census released by the Ministry of Statistics and Program Implementation (MoSPI) of India, Women entrepreneurs are not only sourced through well-established business families but are also from different economic conditions, demographics, and various geographical locations of the country. Women are already establishing their businesses in their interests, including sports, media, science, etc., especially those in male-dominated fields(Sharma, 2013).

While pursuing the role of an entrepreneur, women have certain obligations that need to be fulfilled for operating their business before the establishment, through the sustaining period through effective leadership practices as well as management by solving problems efficiently to withstand the competition in the market through which success can be achieved. With the change in times and available opportunities, there is a drastic increase in the percentage of women entrepreneurs in India and globally. Women can enhance their cryptic potential from various sources and implement their knowledge along the competency sets, enabling the female population to come forth and establish their businesses(Gupta et al.2015). When women are passionate enough, and while they strive to be independent, they are ready to face challenges through their paths. Women's passion and individuality make them determined toward their aspirations. Being independent and achieving something very strongly is one of the most important drivers that motivate women to pursue their dreams while managing the aspect of work-life balance. Throughout history, as per Indian traditions, women were only limited to staying at the houses and were responsible for carrying out household chores.

However, as times changed, certain practices changed, and now women are being provided equal opportunities aligned with men in almost every aspect. Yet, there exists an unconscious bias towards women and their entrepreneurship practices, which is slowly depleting as they can prove themselves by standing up to the male-dominated business environment, and someday, women will be breaking the perspective of the glass ceiling provided with the required support and by utilizing the available opportunities. Women are now aware of their rights and work circumstances that enable them to perform to their potential. They are on par with male-established businesses that proved to be better than men's entrepreneurship practices in some cases. Women have been proving themselves occasionally by being one of the significant contributors to economic growth with the best performance amidst the challenges to doing greater good for society. As mentioned, women were subjected only to performing household chores. Indian women had come a long way by overcoming societal negativism. Yet, they have a vast



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scope for the path they have opted for a while. They still need to achieve equal rights and position like the males as India is a mix of various and numerous traditions where the society is male-dominant. Due to these, the female population in India is considered comparatively weaker than the male population, portraying their dependence on men throughout their lifetime. Following the practices of various cultures and systems, women are forbidden from operating in different vital positions even though they have the proper set of competencies and the required talent due to the glass ceiling concept. Despite these obstacles, Indian women are singing their stories of success worldwide by proving themselves and what they are worth. Women are standing firm and are appreciated for what they have been achieving concerning the sectors under which the established business falls. Transformational change in the lifestyle of Indian women was commanded through the social fabric of Indian society in terms of the high educational status of women and varied aspirations for better living. The women leaders are assertive, persuasive, and willing to take risks. They survived and succeeded in this cutthroat competition with their hard work, diligence, and perseverance. Their ability to learn quickly, persuasiveness, open problem-solving style, willingness to take risks and chances, ability to motivate people, and knowledge of how to win and lose graciously are Indian women entrepreneurs.

Evolution of Entrepreneurship in India

Medieval Age: India has the world's greatest and oldest civilization. During the Harappan culture, internal and external trade attracted many countries worldwide. India is rich in arts, crafts, Vedic tools, and foods that have attracted many parts of the world, which led to the rise of entrepreneurship in India during medieval times. Modern & Pre-Independence- Major events occurred in India in this industrialized era when the first cotton mill was established, beginning the rise of entrepreneurship. Tata Group emerged and expanded its business in areas like Tata Steel and Airlines. Independence activities led to an increase in manufacturing and entrepreneurship in India. Post-independence: Post-independence policies emerged, and economic reforms were carried out due to the liberalization of the new industrial policy in 1956. A significant era of entrepreneurship began in 1990 with the establishment of "Economic Policy Reform "in 1991. The New Economic Policy 1991 consisted of three major aspects: Liberalization, Privatization, and Globalization, which enhanced an important role in creating and evolving entrepreneurship in India and led to the establishment of many tech firms like Infosys, TCS, Wipro, and automobile industries like Mahindra, Bajaj, Maruti, etc. Post-2016, many start-ups started to grow, adding "MAKE IN INDIA" by Modi Ji in 2014 -an initiative to create and encourage companies to develop and manufacture products in our county. More money flow in the market, infrastructural development, Indirect employment, and increased services led to indirect effects of the rise of entrepreneurship in India.

Rise of Women Entrepreneurship

Women's entrepreneurship is one of the oldest topics not nurtured and limited to the limelight in ancient days. Women played an essential role as active leaders during the era of independence, and they were very involved in creating and designing jewelry, farming, machinery, handicrafts, and trading. During colonial times, their lives changed due to social and economic factors. Post-independence, things started drifting, and women played important roles in various sectors. The government is essential in encouraging women to work and recreate things by providing technical and financial support through schemes like Mahila Samridhi Yojana, WEP, Training and Employment program support for women, Mudra Yojana for women, and Women Scientists Scheme. Etc. Higher levels of education, trust, loyalty,



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innovative skills, and commitment are the factors that led to the rise of women's entrepreneurship in India.

Covid-19 and women entrepreneurship

Due to the outburst of COVID-19, the epidemic has impacted the economy, and the countries have declined in economic growth. The pandemic has affected many sectors like IT, Technology, Manufacturing, and Agriculture, disrupting trade externally and internationally, further leading to implementation alternatives. E-commerce was a boom, and everything turned to online and slowly hybrid mode. This gap gave many new opportunities to enter the market and showed the world that there is an emergency of dual income to survive, and many women started to work to feed their families. COVID has allowed many women to learn and create new innovative things, using e-commerce to sell their items and changing their hobbies to business, leading to many women entrepreneurs. The pandemic led to the rise of new women entrepreneurs. It affected many existing entrepreneurs in different ways, such as the supply chain distribution, financial constraints and access to capital, shift in demand for products, and client requirements, which led to changes in their businesses (Booma, 2020).

REVIEW OF LITERATURE

Even though women aimed to achieve their aspirations by fulfilling their objectives, they were rewarded and recognized worldwide. Yet, they were subjected to various constraints, such as relations with family, societal differences, and limitations from the different institutes. (Kumar & Singh, 2021) As the industry structure is based on a male-dominated society, women face various challenges across the path of entrepreneurship, from establishing their start-ups to those times of crisis. As per the studies, the most challenging factor women need to overcome is the accessibility to the required resources along with the necessary financial support. As per the facts, we know there is a difference in providing opportunities for females, which displays gender domination among both genders. These unethical practices have limited their access to required resources. The condition of these aspects has not only been considered an economic issue but also has been included as an issue of both state and national levels due to the limitations of finance, which further results in the depreciation of women. (Kumar & Singh, 2021) Across the world, some countries governments have undertaken specific initiatives to provide the required procedures for standardization and enrolment of their businesses to provide support. Yet, this support had minimum significance in promoting women's entrepreneurship practices to pursue their ideas to generate profits while enabling assistance from the state, which has been a minimal aid to women in India during COVID-19. Researchers have looked at other ways to provide the required considerations about the failure of government policies following support for solopreneurs, including entrepreneurs in India. (Kumar & Singh, 2021) The accomplishments and grants of women to grant economic ownership for the development of the economy have been abandoned. Further, this has resulted in dissatisfaction and ineffectiveness of the procedures, whose initial objective was to provide opportunities to utilize the state's resources. Researchers who tried to analyze the drivers leading to such failures have concluded that most of these studies have failed to investigate the drivers leading to such losses based on male-centric views. (Kumar & Singh, 2021) Capital requirements are the essential aspects that significantly impact the while including risk factors, including the scaling of women entrepreneurs. The limitations to the availability of capital sources and other relevant financial resources of the markets serve as the most



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important supporting factor for most South Asian countries. Researchers categorized the relative sources and bargaining power. They stressed that the greater the income levels of the individuals and the more the composition of the equities of an individual, the greater the control over bargaining power. Yet, barely any studies have highlighted women's hardships concerning sustainability in the markets and economies dominated by men. (Kumar & Singh, 2021) Not only considering the markets, but women are also facing several obstacles to the domination of men within families, society, and state institutions during the regular period, even during the pandemic. (Kumar et al. 2021). Based on the analysis conducted by Jay Chandran, he concluded that there is no diffusion of responsibility among small-scale business owners at home and in organizations in developing countries because "people cannot or do not decouple their business from the rest of their lives and maximize its profits." Jayachandran suggested that "further research on women's interconnected decisions about their businesses and family's finances and their business and family obligations is an important priority for understanding and narrowing the gender gap in microenterprise performance." The related literature, which was pre-constructed, analyzed the difficulties faced by women while practicing the concept of entrepreneurship and suggested relevant mechanisms subjected to the areas of family, market, society, non-state institutions, and state institutions along with the boundaries during the pandemic scenario in India. (Kumar et al. 2021). Previous studies found that the formation of related obstacles inhibits the perceptions of women with suitable substantial. Following the perceptions based on resources, researchers considered the systematic assumptions influencing the availability of resources portrayed as the obstacles for entrepreneurs and any other related aspects to such practices. (Shrivastava, Karim, Kwong, & Mili, 2022)

Based on these perceptions, the diversification of required resources procurement significantly impacted the inculcation of the entrepreneurial spirit and further adoption of this concept. The female population's smaller level of entrepreneurial intentions is generally characterized by differences between the genders, which portray that women have been struggling to procure resources and were in further requirement of aid from available channels. (Shrivastava, Karim, Kwong, & Mili, 2022) The aiding schemes of entrepreneurial practices are supposed to provide valuable insights into male working practices and allocate required resources. With financial and social capital allocation, attention is captured by defining the scholarships in developing countries. The availability of external finance depends on the individual's experience and what the business firm is about to offer. The availability of such resources also affects the perceptions of the individuals. In contrast, the absence of the availability of external finance will only result in the diminishment of entrepreneurial spirit. In developed countries, there is a provision of the required capital from external sources to increase the entrepreneurial ecosystems further, where the aid of external finances supports women. Networking significantly impacts these practices by enabling the provision of required resources to establish a business. There might be flexibility in graphing, scaling from the positive to the negative diffusions, resulting in its effect on entrepreneurial practices. Smaller networks may only result in insignificant aid of these resources, while strong networks positively impact these practices. (Shrivastava, Karim, Kwong, & Mili, 2022).Based on studies on women's entrepreneurship, women entrepreneurs, in general, are relatively well educated but lack the opportunities and challenges that women entrepreneurs in India face. Also, it was found that most women start businesses before age 35 after accumulating some work experience somewhere. The Women in Business and Decision-Making Network's report focuses on women entrepreneurs, their problems initiating and running businesses, family background, education, size of companies, and business units. Research on human capital and self-employment has shown that self-employed women differ from employed women on most human capital variables. The study also indicates that self-employed women



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achieve education faster than working women((Koneru, 2017).(Venotha,2022) Based on a study to identify the reasons and factors influencing women's participation in entrepreneurship and explain the hurdles to developing women's entrepreneurship. The factors identified were lack of interaction with successful entrepreneurs, society's disapproval of female entrepreneurs, family responsibilities, sexism, lack of social network, family, and low financial support (Majumder, 2023). A study of recent changes among female entrepreneurs in developing Asian countries. The study focuses primarily on female entrepreneurs in SME businesses based on data analysis and a review of contemporary key literature. Research shows that women's entrepreneurship is gaining attention across all sectors. The study also describes that the proportion of female entrepreneurs in this region is relatively low due to low educational attainment, lack of capital, and cultural or religious constraints (Colaco et al., 2018). Entrepreneurship is yielding to the positive development of business and market by adopting innovation and economic advancement in the era of entrepreneurship, new strategies evolved by women to support their gender despite facing many challenges like gender discrimination, the glass ceiling, and maintaining work-life balance. Self-confidence and self-determination of women have paved the paths to success in a dominant male industry. (Wahid &Risqo, 2021)

The barriers women entrepreneurs face in developing countries are high compared to developed countries. Living and raising in traditional families, limited resources and opportunities, reserved living, and less training and experience in knowledge have been factors that have prevented women entrepreneurs in developing countries from achieving success. (Wahid &Risqo, 2021) The COVID-19 pandemic harmed women and entrepreneurs; there was a 50% reduction in the productivity of women entrepreneurs due to COVID-19 as challenges and responsibilities were more. Most women entrepreneurs from the service industry have had to pause their work during the coronavirus. (Wahid &Risqo, 2021) Social media marketing and digital marketing were the entrepreneurship trends during COVID-19. There was an issue of funding & networking for women entrepreneurs in everyday scenarios, which worsened significantly during COVID-19. As a survival strategy, women entrepreneurs used these platforms to advertise their products & services, as there was zero chance of mobility. Despite the barriers & constraints, women entrepreneurs are yielding to economic growth. She requires support, great networks, efficient human capital, technological knowledge, innovative skills, and emotional strength to sustain herself in the environment successfully. (Wahid &Risqo, 2021) By enhancing gender equality, there is a significant statistical relationship between gender-related economic development and women's entrepreneurial activities. (Gupta & Aggarwal, 2015)

It is essential that women change their mindset and stop being confined to walls and obligated to societal decisions to take up firm decisions, support other women, and stay motivated to motivate existing entrepreneurs to enhance their entrepreneurship & innovative skills to reach greater heights. Despite the barriers & obstacles, women are one of the most significant reasons contributing to the high level of economic growth. I want to conclude with a famous saying by Dr. A.P.J Abdul Kalam: "Empowering Women is a prerequisite for creating a good nation; when women are empowered, a stable society can be assured. Women's empowerment is essential as their thoughts and value systems lead to the development of a good family, society, and ultimately a good nation". (Gupta & Aggarwal, 2015) According to the insights provided by various studies, it can be summarized that women who play an entrepreneurial role are those from well-educated backgrounds but are limited to specific drivers, such as the proper set of management skills, and their perception towards their values and other drives are not anticipated accurately. There is a sense of differentiation among the women entrepreneurs based on their



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backgrounds, as their fathers are mentoring some, while the rest do not learn from experts. It is concluded that women start their businesses before the age 35 after acquiring some experience, and the obstacles in the growth of women's entrepreneurship are lack of interaction, networking, low family support, funding, updated factors, low level of education, and cultural/ religious constraints. (Afshan, et al 2021) For an entrepreneur, creating a venture is the crucial part through which knowledge is created and disseminated, enriching their entrepreneurial business. At every level of knowledge creation, each step will be a new learning enhancing risk management, innovative skills & abilities. Learning will be affected by individual behaviors and psychological mindsets; apart from these, the interaction of social & environmental aspects will impact learning, like networks, location, communities, resources, and opportunities. Micro-drivers affect cultural norms and demographics, including knowledge, experience, and motivation to accomplish specific objectives in persuading their ideas. Learning, adapting, and applying the inculcated knowledge is different across genders. (Gupta & Aggarwal, 2015).

A study was conducted with the deal to learn about women's entrepreneurship and its associated challenges in India. The study was grounded on secondary data from colorful journal papers and observation. It was established that the imbalance between career and family, lack of trust and support from family, low ignorance or poor education, marketing and entrepreneurial skill inefficiency, and lack of self-confidence were the main challenges for women entrepreneurship in India. (Solanki, 2019) The studies on the growth of women's entrepreneurship mentioned that women had unfolded ahead of limiting themselves to the kitchen and entering into business. The main boosters to develop women's entrepreneurship include technology, skill, rigidity, and backing schemes. The study was on secondary data in colorful reports and journal papers. (Solanki, 2019)

Positive feelings broaden a person's existing studies and actions similar to that, hence becoming more flexible and effective in taking up advanced enterprise. As these individuals broaden their cognitive perspective, their inventories of managing and growing strategies are expanded, bringing them to a better position to follow more adaptive and visionary ways of structuring and using coffers (Kaur et al.). Women must be given equal chances as men in entrepreneurship, as most talented women have liabilities at home. Despite facing many socio-profitable problems, women entrepreneurs and originators have succeeded. With a little further stimulant from the government, a change can be brought to how advanced education institutions foster entrepreneurship and invention in women scholars. Thus, more women entrepreneurs are picking up design as a catalyst in women's entrepreneurship. Transformation can be possible when women's educational status is better. Establishing Women's Study Centres in Technical sodalities will be a strategic move to encourage women entrepreneurs. Some of the ways these women's study centers in advanced education should borrow mentoring the youthful women scholars in entrepreneurship areas similar: Entrepreneurial routes should be fetched to universities for shops, conferences, and forums to encourage women scholars. Participating in their entrepreneurial trip might motivate other women scholars. Women should be encouraged to think logically in addition to finance, threat-taking, communication, etc. Entrepreneurial courses to be conducted give clear guidance, which helps women scholars handle unforeseen situations. (Archana et al. 2022)



**Keerthi Chandrika and Bhanumathi****Statement of the Problem**

With the change of era and growing opportunities with the provision of required resources, while technology aids the needs, individuals can take a step forward to start their businesses by utilizing them rightfully. India, reputed for its culture, produces several women entrepreneurs by promoting them in various ways. Women are projecting their ideas and aspirations and are trying to opt for innovative experimentation and implementation, which are turning out to be potential drivers contributing a justifiable part to the Indian economy. Yet there are specific challenges women as entrepreneurs encounter in establishing their start-ups and operations, especially during COVID-19. Women had limited to various difficulties. This study briefs about women's challenges, especially during the pandemic, and the challenges subjected to pre and post-COVID scenarios.(Arvind, et al. 2023)

Objectives of the Study

- To acknowledge the work-life-balance traits of women entrepreneurs
- To understand the challenges faced by women entrepreneurs pre and post covid
- To interpret the sustainability prospect of women-start-ups in a competitive environment.
- To validate the support of government and private entities to enhance the sustainability of women entrepreneurs and their start-ups.

Scope of the Study

The study focuses on the challenges and opportunities of women entrepreneurs during pre and post covid. The scope of this study is limited to all the females residing in India specified to the category concerning entrepreneurship practices. The research will gather data about the challenges women entrepreneurs face and the opportunities that lead to developing their businesses, networking building, and the factors affecting their businesses. The data collection took place in April 2023.

Conceptual framework Hypothesis

Ho1: There is a significant relationship between work-life prospects and the practices of women entrepreneurship.

Ho2: The support of entities positively impacts the sustainability of women entrepreneurs.

RESEARCH METHODOLOGY

To understand people's attitudes, beliefs, and motivations regarding their social reality, non-numerical (descriptive) data was collected and analyzed using qualitative research methods. Women entrepreneurs across India were considered, and the purposive sampling technique was used to manage the data for the research. The sample size of the study is 15. Primary data was through interviews, telephone interviews, and surveys. The secondary data is from research papers, articles, and journals. Contextual analysis and sentimental analysis are the techniques used to analyze the data for better comprehension of the perspectives and feelings from the interviews.

ANALYSIS AND DISCUSSION

Data was collected from entrepreneurs of different age groups and establishment periods for numerous inputs through Zoom, Google Meet, emails, and telephone interviews. The sample size of the data is 15. The analysis output has provided insights into the following aspects: work-life balance, funding, the





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impact of COVID-19 on their start-ups, stereotyping, challenges faced and the opportunities identified, and support from the private and public entities.

AGE GROUPS OF WOMEN ENTREPRENEURS

According to data collected, 33% were from the age group 18-26,40% were from the age group 27-34, 20% were from the age group 35-42, and 7% were from the age group 43-50. Most of the entrepreneurs are from the age group 27-34.

ESTABLISHMENT PERIOD

According to the data collected from the above graph, 40 % of start-ups were established pre-covid, 26.66 % during covid, and 33.33 % post covid. Out of 15 interviews collected, most of the entrepreneurs started their businesses pre-COVID, and it is observed that start-ups increased post-COVID. In the above graph, 1 represents pre-COVID, 2 illustrates covid, and 3 represents post-COVID.

FUNDING SELF INVESTMENTS / BANK

According to the data collected, the graph shows that 60% of women entrepreneurs have self-invested in their businesses without the government's help.40%of women preferred to take loans from the banks.

Work-life balance as a challenge and its traits

The analysis found that most women face multiple work-life balance issues. Most wanted to start their own business, so they tried to make their hobby a reality. During the establishment, for the first time, they realized that reconciling their personal lives with their professional lives was a complex act. It was difficult for them to do everything themselves. One of them quoted the phrase, "Karma is Dharma." There will be no development if there is a job prospect, no matter what service it receives. These women enjoy their jobs because they have chosen a different path than doing regular jobs based on their interests. Balancing employee leadership with family leadership at home is a significant challenge. But because they are motivated, they stick with them by taking their responsibilities, following the basics of their work, planning accordingly, teaching Agile methods, and selecting the right people. One was a student, so she started working in her junior year of college. She said she could not attend to her duties at night to ensure safety due to the need to travel to different locations at different times. A minority of the population was married and had children. Balancing personal life and work was even more difficult for these women. However, their passion allowed them to start small (step by step) with a dream and overcome some difficulties.

Factors that affected the growth of the start-up

Positive: There was always constant support from family and friends. Meeting the client's expectations was always a positive factor, which made retention and attracting new clients possible. Choosing the right people at the right time assisted the business's operation. AS women, being flexible with their work schedules and tolerance level has helped them stay amidst the restraining factors. Performance was one of the critical aspects that had to be managed, so these individuals measured their performance and took suitable measures to overcome the diffusion of the same from the actual line of expected performance. Social media helps them market their products or services and connect them to various available sources. Hiring the right talent who is willing to accept the start-up's dynamic nature and perform multiple tasks when and wherever required is essential for every stakeholder. All their passion for work made them strive hard toward their vision. Negative: COVID-19 impacted the whole economy. These individuals



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were responsible for managing the employees when there was more work pressure on them; they needed to use some agile methodologies, and, in some cases, emergencies could not be avoided. In some scenarios, there may be failures in fulfilling the prerequisites defined by the customers and customers, too. Sourcing of finance is one of the most critical aspects that had been a hardship for the operation and performance of their start-up. These competitors push us both positively and negatively. They create a sense of awareness so we can learn from them and adopt various methodologies they follow.

Sustainable practices implemented by the women entrepreneurs

The start-up focuses on sustainable practices, striving to be self-sustained without relying on loans or external investors. They have achieved organic growth and financial self-sufficiency, allowing them to operate without answering to shareholders. The company emphasizes empowering employees through opportunities for career growth and certifications, fostering effective communication within the organization. They have adopted efficient and sustainable product creation methods, such as utilizing leftover materials to create complimentary customer bags during deliveries. Recognizing the importance of every stakeholder, the start-up prioritizes hiring the right talent, individuals who are adaptable to the dynamic nature of a start-up, possess multitasking abilities and are quick thinkers. Integrated management techniques are employed to ensure smooth operations. Sustainability practices extend to the employees, as they are offered a commission-based structure consisting of a salary and a commission from sales, further motivating and incentivizing their performance. For women entrepreneurs, the start-up acknowledges the need to balance time between work and family, emphasizing that once family needs are met, support and understanding will follow. Additionally, the company produces eco-friendly products, builds networks, provides training, and focuses on social entrepreneurship. Optimum resource utilization, creating employment opportunities, and empowering individuals are critical aspects of their business approach. The start-up actively engages in workshops, awareness programs, and campaigns to promote sustainability and positively impact the community.

Level of stereotyping

Out of the 15 entrepreneurs, 10 faced stereotyping based on various factors. Being a woman brought biases and challenges at every point, but the support of family and friends played a crucial role in pushing them forward during these instances. Some entrepreneurs experienced stereotyping while pitching their ideas due to their appearance or age. Stereotyping cases were also observed in interactions with bank employees regarding capital requirements and based on personality traits. However, there were both positive and negative aspects to consider. Some challenges were not immediately visible, but building credibility as a woman in a field where societal expectations were against it proved a significant hurdle. Yet, there were instances where hard work and determination garnered support and made people more accommodating. The initial three months were particularly challenging for a few entrepreneurs due to stereotyping, but the situation improved once they established themselves in the market. Others did not face much stereotyping and had supportive individuals around them. One entrepreneur faced stereotypes but viewed each day as a learning opportunity. They relied on word-of-mouth networking and stood out by selecting unique sarees. While some entrepreneurs faced stereotypes and lacked support from their families, they pursued their passion regardless of societal expectations. However, solid support from spouses and families diminished the chances of experiencing stereotyping for another entrepreneur. A significant number of entrepreneurs encountered stereotyping in various forms. Support from loved ones, resilience, and determination was vital in navigating these challenges. The acceptance



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and appreciation from family and the ability to prove oneself led to a more favorable environment for some entrepreneurs.

Impact of covid on start-ups

The impact of COVID-19 on start-ups varied among the entrepreneurs, with 7 out of 15 benefiting from their businesses related to health, mental well-being, nutritious food, or online app development. However, the pandemic posed a significant setback for one entrepreneur who desired to expand her business. Amid the rat race for survival, companies had to find alternatives, such as implementing door-to-door deliveries, and the demand for e-commerce apps skyrocketed. The world opened up to working from home (WFH) as a post-COVID norm. While building their business during the pandemic was challenging, the increased health awareness among people post-COVID had pros and cons, leaving the entrepreneur neutral. Another entrepreneur focusing on millet, healthy nutrition, and avoiding sugar and refined flour found their business highly benefited from COVID-19. For some entrepreneurs, COVID-19 presented both crises and opportunities. Many firms closed down, opening space for new clients and allowing them to manage their businesses better. The market was scarce during the pandemic as people went out less, but entrepreneurs could adapt and make do with the available resources. While COVID-19 harmed some entrepreneurs' businesses, such as increased rent payments despite a lack of work, it also presented an opportunity for learning and acquiring new skills. The impact of COVID-19 on start-ups varied, with some experiencing significant benefits while others faced challenges. Adaptation and finding opportunities amidst the crisis were crucial, with increased awareness of health and changing consumer behavior shaping the outcomes for different entrepreneurs (Kumar et al.,2021)

Challenges faced during the establishment of the start-up

Starting a start-up without any support or government assistance presents numerous challenges. One major hurdle is dealing with the complexities of the Goods and Services Tax (GST) system, as collecting taxes from customers who may be unwilling to pay can be difficult. As a start-up, paying these taxes falls on the entrepreneurs themselves. Managing the business and satisfying clients is also daunting, mainly when losses occur early. The entrepreneur has to navigate the complexities of the art industry, making decisions about materials and time management. Additionally, there is an awareness gap in the food processing sector, which poses a significant hindrance. Overcoming this obstacle is essential for success. Despite the challenges, the entrepreneur's passion and belief in her vision drive her forward. Gaining people's trust and establishing credibility is a challenging endeavor, but it is crucial for the growth of the business. The competitive nature of the job market, coupled with the difficulty of managing a full-time job alongside the start-up, adds further complexity. As a housewife, the entrepreneur faced initial uncertainty, but she found her path and learned to balance her time between family and business. The acceptance from her family and the acquisition of clients were essential milestones that contributed to her success (Solanki, 2019).

Support through govt schemes and entities

Most of the individuals had not been aided by any support from the government, while only three individuals were given the required approval from the government. One received funds from the start-up India initiative, and two lakhs from we-hub aided the other.



**Keerthi Chandrika and Bhanumathi****Women supporting women start-ups**

Women supporting women start-ups play a crucial role in fostering a more diverse and inclusive environment by providing the necessary support and resources that empower women entrepreneurs to overcome barriers and succeed in their ventures (Prashar,2018) Women supporting women start-ups is a supportive initiative that can take businesses to the next level. Women are better decision-makers than men. Women working in higher positions tend to be inspirational, which enhances the empowerment of women supporting women, and many others can learn from them. Women in this competitive world should have the mindset to overcome the fear of male domination. When woman are provided with good education and minimal resources, she has the power to utilize their knowledge to the fullest and implement innovative ideas. It is perceived that when women can manage the house effectively, they can handle the work effectively. A woman can be an excellent mentor to other women and help in collaborations and building networks.

Objective -wise discussions**To acknowledge the work-life-balance traits of women entrepreneurs**

According to the analysis, most women faced several work-life balance issues. Most aspired to start a business and converted their hobbies into action. Initially, during the establishment, they found that aligning personal life to differentiate from professional life was a complex practice. They found it challenging to manage everything by themselves. As one of them quoted, "Karma is Dharma"; if there is the prospect of work, there would be no development irrespective of the services it is subjected to. These women enjoyed their work as they opted for a different path rather than performing the regular job as it was determined based on their interests. It is very challenging to balance the management of employees at work and family at home. Yet, due to their motivation, they were holding on to them by fulfilling their responsibilities by following the basics of working, planning according to (the timetable), choosing the right people, and teaching agile methodologies. As one of them was a student, she began working in the 3rd year of academics; she quoted that there was a need to travel to various locations at different times of time, which limited her to performing her duties during the night as she was reluctant to security. Minor groups of the population were married and had kids. These women found it more challenging to manage their personal and professional lives. Yet, due to their passion, they could come home and cope with the difficulties by starting small (step-by-step) while dreaming.

Sentimental Analysis Score is = 0.13

The sentiment is positive, and we see that women managed their work and personal lives by prioritizing and scheduling things. This study shows that women struggled to balance their personal and professional lives. Amidst these difficulties, they have drawn a line between personal and professional life. Women are more challenging and successful yet face few difficulties. It is said that there should be proper agenda and timetables to balance work and life.

To understand the challenges faced by women entrepreneurs pre and post covid.

The COVID-19 scenario had a dreadful impact on the world as it significantly impacted everyone, irrespective of their profession. Women striving hard to establish themselves or in the middle of expanding their start-ups found it challenging to operate as the question of existence was a complex contradiction. Most of the operations of these businesses were going on par with the designed strategies, and some had planned on expanding their companies. Due to the effect of COVID-19, they failed to grow their business accordingly. The nations' economies had significantly depleted, and the sourcing of finance



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for the countries was limited. Women had found it very difficult to source finance amidst the crisis scenario. Some found operating difficult, while others worked remotely to continue their operations. The Pandemic Scenario had positive and negative impacts on women. Some invest a lot of time in planning and executing the process while learning new concepts and implementing them into the business to increase efficiency. One of the entrepreneurs had designed and implemented the right course of action by establishing her start-up and further operating amidst the pandemic.

To interpret the sustainability prospect of women-start-ups in a competitive environment.

Most women aim to withstand the competition by making a name for themselves and optimizing the available resources. As one of the states, the leftovers from the production of end items were used to produce aesthetics and are given as complementarity to the customers to retain and satisfy them. As financing was from self-sources, there was no question of being pointed to anyone. Yet, there are issues with the retention and sustainability of the employees as the expected quality differed from the produced quality in some cases (Raman,2022). Even without financial aid, most women were prone to establish strong networks to sustain themselves amidst the competition. There are always drivers that would affect the performance of the individuals, impacting the overall output of the establishments. Either way, people are a source of criticism, and at such times, one needs to stay strong and move forward; even if the attempt is to fail, you will be satisfied and will be learning from the failures, which results in improved efficacy in the future. One of the individuals was prone to use digital marketing practices to build networks she could sustain in the entrepreneurial environment. Last, the most common thing all the individuals felt was treating the customers correctly while understanding their needs would retain many of them. By being innovative, new customers could be attracted and encouraged to consume their product. Sentimental Analysis Score is = 0.22 The study shows that despite the pandemic, women have adapted to new technologies and methods to sustain themselves in the market and make profits.

The critical element is stakeholder management and business management. The new era has given women many opportunities, and we see a positive sentiment, implying that most women sustained in the pandemic and utilized the opportunities. To validate the support of government and private entities to enhance the sustainability of women entrepreneurs and their start-ups. Most of the women felt that there was no assistance from the government entities; instead, they had a negative impact. Any entity, irrespective of the type of operations, must pay taxes to the authorities. They were limited to charging these taxes from the customers, so they needed to provide the same from their earnings, decreasing the total revenue generated. Most of them had started their establishments from their savings, and there were cases of 3 entrepreneurs who had received the required assistance along with a small part of the total investments from the schemes of the Indian government (Start-up India.). While some of them mentioned that they had been applying for loans from the banks, and eventually, their requests got rejected, a monetary source was required, which was further allocated through their savings, family, and friends(Rani,2023).

SUGGESTION AND CONCLUSIONS

Some of the suggestions based on the research study are as follows: Despite the available opportunities, women fail to make the right choices that would impact the performance of their establishments. Enhancing mentoring programs by experienced women would increase and empower the number of



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female entrepreneurs in the economy. Most women fail due to the various market challenges and Women passionate about converting their ideas and hobbies into business encountered various challenges through their conversion path. Being an entrepreneur was never easy for them as multiple factors directly/indirectly caused their growth. As per the different studies and the integration of findings, we can conclude that women were stereotyped and limited by factors such as finance, networking, a suitable customer base, and awareness. They were working hard to maintain a work-life balance. They had been striving hard to draw a line between personal and professional life as women were prone to many responsibilities dealing with their personal lives. It was challenging, yet their passion for the work and motivation towards their power drove them to continue their work and progress accordingly. Covid had positive and negative impacts on these entrepreneurs as they faced several challenges in their operations. Planning to expand their business was negatively impacted, and due to the limitation of monetary rotations in the economy, the concept of existence itself had been challenging for them. On the other hand, some had a lot of time planning and implementing the most appropriate operations while working remotely with the teams. Post-COVID, some challenges acted as resistors to growth, resulting in minimal effectiveness. To sustain, we need to adopt the exemplary aspects, and women who found the element of financial investments were on par with their sustainability requirement to invest from their savings. Only a minority of them were supported by the government's initiatives through financing, which was considerably low. Even the private entities were reluctant to provide the required aid. Only through networking were these women able to source their finances and construct a web of networks to attract customers and thrive to sustain themselves among the competition(Solanki,2019).

REFERENCES

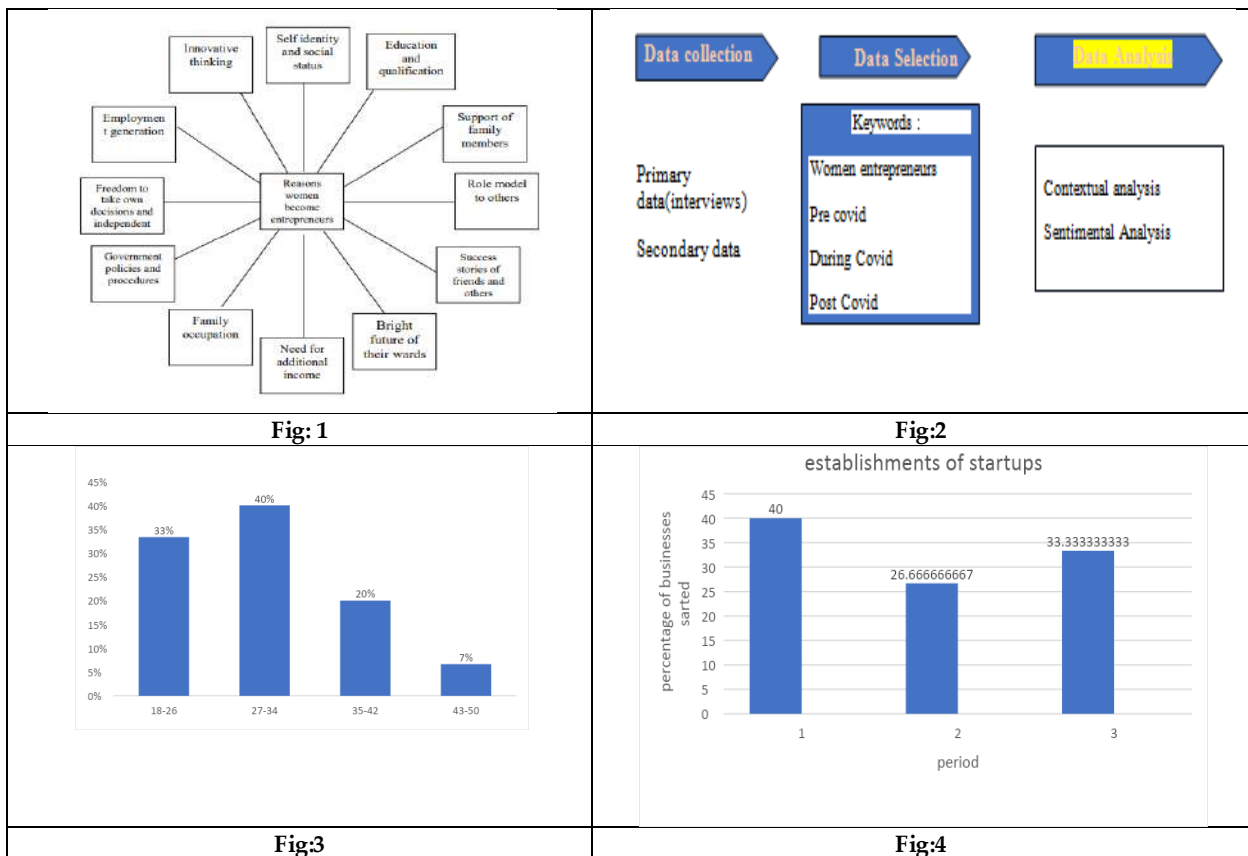
1. Afshan, G., Shahid, S., & Tunio, M. N. (2021). *International Journal of Gender and Entrepreneurship*, 35.
2. Archana, Vijaya, K., & Shyamasundar. (2022). Women Entrepreneurship and Innovation in Higher Education: Opportunities and Challenges in India. *Journal of Engineering Education Transformations*, 37-44.
3. Arvind, T., & Ranjith, P. V. (2023, May). Women Entrepreneurship: Challenges and Solutions-An Exploratory Study. In International Conference on Emerging Trends in Business and Management (ICETBM 2023) (pp. 276-283). Atlantis Press.
4. Booma, T. (2020). Impact of covid 19 on women entrepreneurs-opportunities and challenges in informal sectors. In *impact of women empowerment* (p. 98). Madurai: Shanlax Publications.
5. Borah, A. J., & Bhowal, A. (2023). Gender Culture and Entrepreneurship: Exploring Challenges and Opportunities. *International Journal of Progressive Research in Engineering Management and Science*. 15 (7), 390, 395.
6. Colaco, V., & Hans, V. (2018). Women Entrepreneurship in India—Changes and Challenges.
7. Gupta, S., & Aggarwal, A. (2015). Opportunities and Challenges faced by Women Entrepreneurs in. *IOSR Journal of Business and Management*, 5.
8. Kaur, S. G., Pratik, M., & Stanzin, M. (2023). New product innovations in times of crisis: How did women entrepreneurs survive the COVID-19 crisis? *Industrial Marketing Management*, 19-29.
9. Koneru, K. (2017). Women Entrepreneurship in India - Problems and Prospects. *VFSTR*, 12.
10. Kumar, S., & Singh, N. (2021). Entrepreneurial prospects and challenges for women amidst COVID-19: a case study of Delhi, India. *Fulbright Review of Economics and Policy*, 22.
11. Majumder, S. (2023). Women Entrepreneurship in Industrial Revolution 4.0: Opportunities and Challenges. *Constraint Decision-Making Systems in Engineering*, 177-203.
12. Prashar, S., Vijay, T. S., & Parsad, C. (2018). Women entrepreneurship in India: a review of barriers and motivational factors. *International Journal of Entrepreneurship and Innovation Management*, 22(3), 206-219.





Keerthi Chandrika and Bhanumathi

13. Raman, R., Subramaniam, N., Nair, V. K., Shivdas, A., Achuthan, K., & Nedungadi, P. (2022). Women entrepreneurship and sustainable development: Bibliometric analysis and emerging research trends. *Sustainability*, 14(15), 9160.
14. Rani, V. S., & Sundaram, N. (2023). Opportunities and Challenges Faced by Women Entrepreneurs for Sustainable Development in India. *Journal of Law and Sustainable Development*, 11(10), e438-e438.
15. Sharma, R., Sharma, A., Rana, G., & Jain, V. (2022). Woman Entrepreneurship in India: A Paradigm Shift. In *Entrepreneurial Innovations, Models, and Implementation Strategies for Industry 4.0* (pp. 117-136). CRC Press.
16. Sharma, Y. (2013). Women entrepreneurs in India. *IOSR Journal of Business and Management*, 15(3), 9-14.
17. Solanki, N. (2019). WOMEN ENTREPRENEURSHIP: A PARADIGM SHIFT. *Humanities & Social Sciences Reviews*, 4.
18. Venotha, A. S., & Mariadoss, D. S. (2022). WOMEN ENTREPRENEURSHIP IN INDIA: A LITERATURE REVIEW. *International Research Journal of Modernization in Engineering Technology and Science*, 4(1), 1608-1615.
19. Wahid, & Risqo. (2021). Women MSMEs and Covid-19: Social Media. *International Journal of Innovative Science*.





Keerthi Chandrika and Bhanumathi

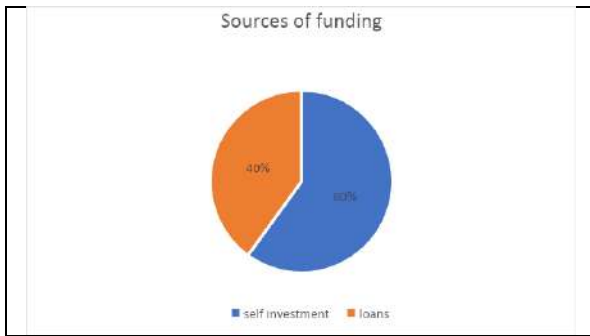


Fig:5



Fig:6





Simplified Kundalini Yoga: A Study on Its Impact on Stress Reduction and Life Satisfaction in Men with Alcohol Addiction

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ABSTRACT

The primary objective of simplified Kundalini yoga is to attain inner peace by fostering harmony between the mind and spirit. Consequently, it presents valuable opportunities for enhancing stress management and overall life satisfaction. This quasi-experimental study, utilizing a pretest-posttest control group design, seeks to investigate the impact of an eight-week Simplified Kundalini yoga program on stress levels and life satisfaction in men struggling with addiction. Twenty participants aged between 35 and 55, divided into an experimental group (n=10) and a control group (n=10), were enrolled in the study. Data collection involved a descriptive information form, the Depression Anxiety Stress Scales (DASS-21), and the Satisfaction with Life Scale (SWLS). The results were analyzed using paired and unpaired t-tests. Following the Simplified Kundalini yoga intervention, the experimental group exhibited a significant decrease in stress scores ($p=0.001$) and a noteworthy increase in satisfaction with life scores ($p=0.001$). Conversely, there was no significant difference observed in the control group during the same period ($p>0.050$). These findings suggest that Simplified Kundalini yoga proves to be an effective approach for reducing the stress and improve life satisfaction among men grappling with alcohol addiction. Further research with larger sample sizes, including follow-up measurements, is recommended for a more comprehensive understanding of its long-term efficacy.

Keywords: Simplified Kundalini Yoga, DASS-21, Satisfaction with Life, middle aged men.



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INTRODUCTION

Simplified Kundalini Yoga is a form of yoga that has gained popularity in recent years due to its potential to improve overall well-being. This practice involves specific techniques and principles that aim to awaken the dormant energy within the body, known as Kundalini. In this essay, we will explore the benefits of Simplified Kundalini Yoga, its impact on stress reduction and life satisfaction, and its potential to treat alcohol addiction in men. Understanding Simplified Kundalini Yoga is a unique form of yoga that involves specific techniques and principles to awaken the dormant energy within the body. This practice is based on the teachings of Vethathiri Maharishi, a spiritual leader from India. The principles of Simplified Kundalini Yoga include physical postures, pranayama (breathing exercises), and meditation. These techniques are designed to balance the energy centers within the body, leading to improved physical, mental, and emotional health. Research studies have shown that practicing Simplified Kundalini Yoga can have numerous benefits, including stress reduction, improved sleep quality, and increased energy levels. Additionally, this practice has been shown to improve overall well-being and increase life satisfaction.

Research studies have shown that practicing Simplified Kundalini Yoga can have a significant impact on stress reduction. A study published in the Evid Based Complement Alternat Med found that participants who practiced Kundalini Yoga for eight weeks experienced a significant reduction in stress levels compared to a control group. Furthermore, the reduction in stress levels has been shown to have a positive impact on overall well-being and life satisfaction. A study published in the International Journal of Yoga Therapy found that participants who practiced Kundalini Yoga reported increased levels of life satisfaction and improved overall well-being.

Alcohol addiction is a complex condition that is often linked to stress and anxiety. Research studies have shown that practicing Simplified Kundalini Yoga can help address the underlying causes of addiction by reducing stress and anxiety levels. A study published in the Journal of Addictive Diseases found that men who participated in a Simplified Kundalini Yoga program experienced a significant reduction in alcohol cravings and an improvement in overall well-being. Additionally, the study found that participants who continued to practice Simplified Kundalini Yoga after the program had a higher rate of sustained abstinence from alcohol.

METHODOLOGY

Study Design: This study aimed to investigate the effects of Simplified Kundalini Yoga on subjects undergoing a residential alcohol de-addiction program at the V Can foundation trust (MCF) in Chennai. The study employed a quasi-experimental study with two groups: Group I (Simplified Kundalini Yoga group) and Group II (control group).

Participants: Twenty male patients aged between 35 and 55 were recruited for the study. Inclusion criteria included being chronic alcoholic patients in active dependence, willingness to participate in Yoga therapy, and the ability to perform the prescribed techniques. Exclusion criteria comprised complications caused by alcohol such as giddiness, seizures, memory problems, etc.

Randomization: The 20 participants were randomly assigned to either Group I or Group II. Group I received Simplified Kundalini Yoga, while Group II served as the control group and received only usual health assessment.

Intervention: The Simplified Kundalini Yoga protocol was administered for 60 minutes daily, six days a week, over a span of four weeks. Participants in both groups continued with their usual health assessment throughout the study period.

Outcome Measure: The Depression Anxiety Stress Scales (DASS-21), the Satisfaction with Life Scale (SWLS) was used to assess the participants'. The scale was administered to all participants in both groups before and after the four-week study period.





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Statistical Analysis: Student's paired t-test for intra-group comparisons and unpaired t-test for inter-group was using for Data analysis. This allowed for the assessment of changes within each group and the comparison of outcomes between the Simplified Kundalini Yoga group and the control group.

Ethical Considerations: The study adhered to ethical guidelines, and all participants provided informed consent before participation. Confidentiality of information was maintained throughout the study. IEC No: MMCH&RI IEC/Ph.D/23/JUNE/22.

Limitations: The study included the small sample size and the shorter duration of the intervention. Further research with larger sample sizes and longer intervention periods may provide more robust insights into the effects of Simplified Kundalini Yoga in alcohol de-addiction programs.

RESULTS

The results are given in table 2 and table 3. The intragroup comparison after 4 weeks of Simplified Kundalini Yoga showed a significant reduction ($p < 0.001$) in the DASS-21 and Satisfaction with Life Scale (SWLS) in group I, but in group II there were statistically insignificant. The intergroup comparisons after 2 weeks of Yogic therapy group showed a significant reduction ($p = 0.001$) in the DASS-21 and Satisfaction with Life Scale (SWLS) than the control group.

CONCLUSION

In conclusion, Simplified Kundalini Yoga is a powerful practice that has numerous benefits for overall well-being (Suresh, et.al, 2013). Research studies have shown that practicing this form of yoga can reduce stress levels (Dr.M.Sarada, 2019), increase life satisfaction, and even help treat alcohol addiction in men. By incorporating the principles and techniques of Simplified Kundalini Yoga into daily life, individuals can improve their physical, mental, and emotional health and achieve a greater sense of well-being.

REFERENCES

1. Saradha, M. (2019). Effect of Simplified Kundalini Yoga on Selected Psychological Variables of College Women Students. *Int J Adapt Phys Educ Yoga [Internet]*, 4(3).
2. Suresh, A., Ramachandran, K., & Jayachander, M. (2013). Effect of kundalini yoga on psychological health in young adults. *Indian Journal of Positive Psychology*, 4(1), 7.
3. Jenila, T., & Valliammal, G. R. (2016) Simplified Kundalini yoga practices on selected psychological aspect of women. *International Journal of Yoga and Allied Sciences* (ISSN: 2278 – 5159) Volume: 5, Issue: 1, pp.49-52
4. K. K. Aathava and Dr. M. Jothilakshmi, (2016)Vethantham to Vethathiri Yogam. *International Journal of Yoga and Allied Sciences* (ISSN: 2278 – 5159) Volume: 5, Issue: 1, pp.63-69.
5. Jindani F, Turner N, Khalsa SB. A Yoga Intervention for Posttraumatic Stress: A Preliminary Randomized Control Trial. *Evid Based Complement Alternat Med*. 2015;2015:351746. doi: 10.1155/2015/351746. Epub 2015 Aug 20. PMID: 26366179; PMCID: PMC4558444.
6. Gabriel, M. G., Curtiss, J., Hofmann, S. G., & Khalsa, S. B. S. (2018). Kundalini yoga for generalized anxiety disorder: an exploration of treatment efficacy and possible mechanisms. *International journal of yoga therapy*, 28(1), 97-105.
7. Vethathiri, Maharishi (2002). Manavalakalai – I, Erode, *Vethathiri Publicaitons* pp.07 & 16 Vethathiri Maharishi (2009). Yoga for Modern Age, Erode, *Vethathiri Publications* pp.33 & 36





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Table 1: List of intervention given to the subjects

Name of Practice	Duration
Opening prayer	1 min
Hand practice 7 postures, Leg practice 7 postures, Breathing practice, Eye practice, Kapalabhati, Massage, Acupressure	55 mins
Relaxation	2 mins
Closing prayer	1 min

Table 2: Pre and post test scores of DASS-21 of simplified kundalini yoga and control group undergoing a residential alcohol de-addiction program

	GROUP I	GROUP II	INDEPENDENT T VALUE AND P VALUE
	Mean±SD	Mean±SD	
PRE-TEST	43.20±5.846	49.10±6.173	t=14.065, p<0.000***
POST TEST	20.10±4.630	44.00±6.254	
PAIRED T VALUE AND P VALUE	t=9.620, p<0.000***	t=1.697, p<0.124(N.S)	

Note: N.S – Not Significant, ***Significant at 0.001 level of confidence

Table 3: Pre and post test scores of Life satisfaction of simplified kundalini yoga and control group undergoing a residential alcohol de-addiction program

	GROUP I	GROUP II	INDEPENDENT T VALUE AND P VALUE
	Mean±SD	Mean±SD	
PRE-TEST	12.00±1.764	10.20±2.044	t=4.679, p<0.000***
POST TEST	26.90±2.644	9.60±1.430	
PAIRED T VALUE AND P VALUE	t=20.214, p<0.000***	t=0.732, p<0.483 (N.S)	

Note: N.S – Not Significant, ***Significant at 0.001 level of confidence





Advances and Future Frontiers in Microbial Bioremediation of Oil Contaminated Environments

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ABSTRACT

Environmental and ecological problems are greatly increased when oil contaminates both land and aquatic habitats. Restoration of oil-contaminated sites has found a viable and sustainable solution in bioremediation, especially where microbial action is involved. This paper offers a thorough examination of current developments in microbial bioremediation methods used on oil-contaminated sites, emphasizing the mechanisms driving hydrocarbon microbial breakdown. We examine several approaches used to boost microbial productivity and activity, such as genetically modified microorganisms, bioaugmentation, and biostimulation. We also investigate the effects of ambient conditions on microbial-mediated bioremediation processes, including temperature, pH, and nutrient availability. Additionally, the review emphasizes the difficulties and constraints related to microbial bioremediation, such as the requirement for ongoing site recovery monitoring and the possibility of microbial resistance. Lastly, we talk about potential future developments and cutting-edge technologies like metagenomics, synthetic biology, and nanotechnology that could propel the area of microbial bioremediation forward. This review seeks to aid in the creation of practical and long-lasting plans for the microbial bioremediation of oil-contaminated sites by consolidating current research findings and pinpointing important areas for further investigation.

Keywords: Bioremediation, Environmental restoration, Hydrocarbon degradation, Bioaugmentation, Environmental factors, Long-term monitoring, Metagenomics.





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INTRODUCTION

The pollution of natural settings by oil presents a serious risk to human health, ecological stability, and biodiversity, affecting both terrestrial and aquatic ecosystems (Hader et al.,2020; Lin et al.,2024). Air quality, water bodies, and soil can all be negatively impacted by widespread pollution caused by spills from industrial, transportation, and oil exploration activities. Complex mixes of hydrocarbons, heavy metals, and other hazardous substances found in crude oil and its refined derivatives can linger in the environment for long periods of time, having a negative impact on both biotic and abiotic elements (Swapnil et al.,2023). Chemical dispersants and mechanical confinement are two examples of traditional oil spill cleaning techniques that might increase environmental dangers while having a limited effectiveness(Adofo et al.,2020). As a sustainable and eco-friendly method of lessening the effects of oil contamination, bioremediation has drawn more attention in recent years. The process of bioremediation uses microorganisms' innate ability to break down hydrocarbons into innocuous byproducts, eventually returning the contaminated area to its pre-contamination form.

Oil Contamination

Numerous anthropogenic activities, such as runoff from cities, storage facility leaks, and unintentional accidents, can contaminate soil with oil. Large amounts of crude oil or refined petroleum products may spill during these events and endanger groundwater, surface water, or soil, causing extensive pollution. A number of variables, including the kind of oil spilled, its amount released, the environment's features, and its closeness to delicate ecosystems or populated areas, might impact how serious an oil pollution is (TelliKarakoc et al.,2020; Kour et al., 2023). The main constituents of crude oil are hydrocarbons, such as aromatics, alkanes, and polycyclic aromatic hydrocarbons (PAHs), which are hazardous to living things and have a long half-life in the environment(Singhet al.,20220). Furthermore, heavy elements like lead, mercury, and cadmium that worsen environmental degradation may be present in oil spills. These pollutants can bioaccumulate and biomagnify in the food chain, posing long-term threats to ecosystem health and human well-being in soil and sediment (Onyena et al.,2023).

Bioremediation

By using the natural metabolic processes of bacteria, fungus, and archaea, bioremediation breaks down and purges oil pollutants (Patel et al.,20230). With the use of specific enzymes, microorganisms may convert hydrocarbons into less complex molecules via biochemical processes like oxidation, hydrolysis, and aerobic and anaerobic respiration. Under aerobic conditions, oxygen acts as the terminal acceptor of electrons, allowing hydrocarbons to fully mineralize into carbon dioxide and water. In anaerobic environments, microbes break down hydrocarbons into less hazardous intermediates like methane or acetate by using different electron acceptors such nitrates, sulfates, or carbon dioxide (Dharet al.,2020). Intrinsic bioremediation and engineered bioremediation are the two primary categories of bioremediation methods. In order to organically break down oil pollutants, intrinsic bioremediation depends on the native microbial populations that exist in the contaminated environment. A number of variables, including nutrition availability, environmental circumstances, and the presence of inhibitory compounds, may place restrictions on this technique, despite its low cost and minimal invasiveness (Sokal et al., 202). In order to accelerate and improve the pace of oil breakdown, engineered bioremediation manipulates microbial populations or environmental factors (Yang et al., 2021). One possible approach is bioaugmentation, which involves introducing specialized microbial consortia or genetically modified microorganisms to the contaminated location in order to increase the native microbial populations (Nwankwegu et al.,2022). Utilizing biostimulation techniques, native microorganisms' metabolic activity is stimulated by the addition of nutrients, oxygen, or other growth-promoting materials. In addition, methods like phytoremediation—which use plants to boost microbial activity and remediate soil—are drawing interest because of their potential to eliminate oil pollutants from the environment in a way that works well together (Wei et al.,2021).



**Pooja Kasana and Pankaj Kumar Rai****Mechanisms of Microbial Bioremediation of Oil contaminated areas**

Oil pollutants in soil, water, and sediments can be broken down and detoxified by the intricate process of microbial bioremediation, which uses the metabolic activity of several microbial populations (Sharma et al., 2021). Gaining insight into the mechanisms behind microbial bioremediation is essential to improving remediation tactics and the effectiveness of attempts to clean up oil spills. Here, we explore the complex mechanisms that microorganisms use to change and break down hydrocarbons, emphasizing important metabolic chains and environmental elements that affect microbial-mediated bioremediation (Kaya et al., 2024).

Hydrocarbon Degradation Pathways

Microorganisms employ various enzymatic pathways to metabolize hydrocarbons present in crude oil and petroleum products (Huang et al., 2021). These pathways can be broadly categorized into aerobic and anaerobic degradation processes, depending on the availability of oxygen in the environment.

Aerobic Degradation

Hydrocarbons can be fully mineralized into carbon dioxide and water when aerobic conditions are met because oxygen acts as the last electron acceptor for microbial respiration (Wartell et al., 2021). Aerobic hydrocarbon-degrading microbes, including some bacterial species (such as *Pseudomonas* and *Alcanivorax*), oxidize hydrocarbons into metabolically accessible intermediates by using oxygen-dependent enzymes like monooxygenases and dioxygenases. Through further metabolism via major metabolic pathways like the glyoxylate cycle and the tricarboxylic acid cycle (TCA cycle), these intermediates are eventually converted to energy needed for microbial growth and reproduction (Ryan et al., 2021).

Anaerobic Degradation

Microorganisms use different electron acceptors, such as nitrates, sulfates, or carbon dioxide, to convert hydrocarbons into less hazardous intermediates in anaerobic environments, when oxygen is scarce or nonexistent. Generally, fermentative reactions are followed by syntrophic interactions between several microbial species in anaerobic hydrocarbon breakdown pathways (Yadav et al., 2022). For example, methanogenic archaea and sulfate-reducing bacteria (SRB) work together to break down complex hydrocarbons like aromatic compounds and long-chain alkanes through a series of sequential events that include metabolic cross-feeding and interspecies electron transfer.

Biochemical Transformations

In order to make hydrocarbons more susceptible to microbial degradation, a variety of biochemical changes are used in microbial bioremediation (Sharma et al., 2022). The hydroxylation, oxidation, reduction, and ring cleavage processes are among these changes that are facilitated by certain enzymes generated by microbes that break down hydrocarbons. Hydrocarbon monooxygenases, for instance, add hydroxyl groups to hydrocarbon molecules, making them more soluble in water and vulnerable to enzymatic degradation. Analogously, aromatic hydrocarbons including benzene, toluene, ethylbenzene, and xylene (BTEX) molecules are oxidized by dioxygenases and cytochrome P450 enzymes, producing intermediates that can enter central metabolic pathways and undergo additional degradation (Dhar et al., 2020).

Environmental Factors Influencing Bioremediation

Temperature, pH, moisture content, nutrient availability, and the presence of inhibitory chemicals are some of the environmental parameters that affect the efficacy of microbial-mediated bioremediation (Dhar et al., 2022). The particular hydrocarbon pollutants present and the microbial populations involved determine the best conditions for bioremediation. For example, low-temperature psychrophilic bacteria are ideal for bioremediation in cold environments like deep-sea sediments and the polar regions. Analogously, increasing the amount of nitrogen, phosphorus, and trace elements can speed up the rate at which hydrocarbons degrade by promoting microbial development and activity. On the other hand, high levels of heavy metals, salt, or hazardous organic compounds



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might suppress microbial growth and obstruct the advancement of bioremediation (Sharma et al.,2021). As a result, countermeasures must be taken to lessen these negative consequences. A wide range of metabolic processes and biochemical changes that are coordinated by microbial communities are necessary for the effective microbial bioremediation of oil-contaminated environments (Cabral et al.,2022). Utilizing the metabolic powers of microorganisms that break down hydrocarbons, bioremediation provides an eco-friendly and sustainable means of lessening the effects of oil spills and restoring damaged environments. In order to successfully clean up and restore oil-contaminated sites, remediation solutions that are customized to particular environmental conditions and contaminants must be designed with an understanding of the mechanisms underlying microbial-mediated bioremediation (Pande et al.,2020).

Recent Advances in Microbial Bioremediation Techniques for oil bioremediation

The development of effective and long-lasting remediation techniques is imperative due to the substantial environmental hazards posed by oil contamination (Basak et al.,2020). Microbial bioremediation has become a viable strategy for reducing oil pollution because it uses microorganisms' metabolic capacities to break down hydrocarbons. Recent times have witnessed significant progress in the field of microbial bioremediation approaches, with the objective of augmenting the efficacy, adaptability, and practicability of this remediation approach in many environmental contexts. This study covers the latest developments and advances in microbial bioremediation methods for oil contamination, including genetic engineering, bioaugmentation, biostimulation, and new technologies (Sarkar et al.,2020).

Bioaugmentation

Enhancing biodegradation capacities in contaminated areas by the introduction of genetically modified microorganisms or external microbial consortia is known as bioaugmentation (Nwankwegu et al.,2022). The creation of specialized microbial consortia with improved hydrocarbon-degrading enzymes, such as alkane monooxygenases and dioxygenases, to target particular oil components is one of the most recent developments in bioaugmentation methods. Additionally, encapsulation methods including biofilm immobilization and microencapsulation have been used to increase microbial activity, survival, and persistence in contaminated environments. Synthetic biology techniques have also been used to create engineered microbial strains with improved metabolic pathways for oil degradation, opening up customized treatments for certain pollutants and environmental circumstances (Das et al., 2020).

Biostimulation

The goal of biostimulation is to increase the activity and expansion of native microbial populations by providing growth-promoting substances, electron acceptors, or other necessary nutrients (Khatoun et al., 2020). In order to maintain microbial activity over long periods of time, nutrient delivery systems such organic substrates and slow-release fertilizers have been developed as part of recent advances in biostimulation techniques. Furthermore, novel strategies have been investigated to improve the bioavailability of oil pollutants and promote microbial breakdown in low-permeability soils and sediments, including electrokinetic stimulation and bioelectrochemical systems. Enhancing oil removal and site recovery efficiency, the integration of biostimulation with other remediation techniques like electrokinetics and phytoremediation has demonstrated synergistic effects (Aparicio et al.,2022).

Genetic Engineering

It is possible to create customized microbes with improved oil-degrading capacities using genetic engineering, which provides exact control over microbial metabolic pathways (Bora et al.,2023). The main goals of recent genetic engineering developments have been to improve substrate selectivity, catalytic efficiency, and environmental tolerance while also optimizing important enzymes involved in hydrocarbon breakdown. Protein engineering and directed evolution have been used to create enzymes that are more stable and active in a variety of environmental settings (Dinmukhamed et al.,2021). Additionally, the development of synthetic microbial consortia with complementary metabolic roles has been made possible by synthetic biology techniques like genome editing and pathway modification, which have promoted synergistic interactions for increased oil bioremediation effectiveness.



**Pooja Kasana and Pankaj Kumar Rai****Emerging Technologies**

The application of microbial bioremediation for oil-contaminated sites has gained more breadth and capabilities due to recent advancements in new technologies (Okoh et al.,2020). The identification of new enzymes and metabolic pathways for bioremediation applications has been made easier by the thorough characterization of microbial communities and the metabolic routes involved in oil degradation made possible by metagenomic analysis and high-throughput sequencing methods. Moreover, methods based on nanotechnology, like the delivery of nutrients and electron acceptors via nanoparticles, have demonstrated potential in raising microbial activity and oil breakdown rates in contaminated environments (Behl et al.,2022). Remediation efficiency and cost-effectiveness have increased due to real-time monitoring and optimization of bioremediation processes made possible by the integration of remote sensing, machine learning, and predictive modeling techniques. Oil contamination can now be addressed in a wider range of environmental contexts thanks to recent developments in microbial bioremediation techniques (Rahman et al., 2020). Innovative methods to improve the resistance, efficiency, and application of oil degradation include genetic engineering, bioaugmentation, biostimulation, and new technology. Nonetheless, there are still issues with these methods' scalability, long-term efficacy, and environmental safety. Sustained investigation endeavors and cross-disciplinary cooperation are imperative in order to enhance microbial bioremediation tactics and establish viable and economical resolutions for environmental remediation and oil pollution predicaments (Aidarzhanovich et al.,2023).

Challenges and Limitations in Microbial Bioremediation

Using the metabolic powers of microorganisms to break down hydrocarbons, microbial bioremediation is a viable method for cleaning up oil-contaminated areas. Notwithstanding its potential, a number of obstacles and constraints may impede the efficacy and practicality of microbial bioremediation methodologies (Rabbani et al.,2021). Comprehending these obstacles is essential to maximizing bioremediation tactics and successfully meeting environmental cleanup requirements (Refer Fig. 2).

CONCLUSION: IMPLICATIONS FOR SUSTAINABLE REMEDIATION PRACTICES

Bioremediation holds significant promise as a sustainable and environmentally friendly approach to cleaning up contaminated sites. As outlined in the preceding discussions, advancements in microbial consortia, genetic engineering, nanotechnology applications, biostimulation strategies, in-situ remediation technologies, and monitoring and modeling techniques offer opportunities to enhance bioremediation efficiency and effectiveness. These advancements have important implications for the development and implementation of sustainable remediation practices. Here, we delve into the detailed implications of these advancements for sustainable remediation:

Environmental Sustainability

- Bioremediation promotes environmental sustainability by leveraging natural biological processes to degrade contaminants, minimizing the use of energy-intensive and disruptive remediation methods.
- Sustainable remediation practices focus on preserving ecosystem health, biodiversity, and ecosystem services while restoring contaminated sites to functional ecosystems capable of supporting human health and well-being.

Minimization of Environmental Footprint

- Advancements in bioremediation technologies enable the minimization of the environmental footprint associated with remediation activities by reducing waste generation, energy consumption, and habitat disturbance.
- Sustainable remediation practices prioritize the use of low-impact and minimally invasive techniques, such as in-situ bioremediation and natural attenuation, to minimize ecosystem disruption and conserve natural resources.

Cost-effectiveness

- Sustainable bioremediation practices offer cost-effective solutions for addressing contamination issues, with lower capital and operational costs compared to conventional remediation methods.



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- By optimizing bioremediation processes, enhancing efficiency, and leveraging synergistic interactions with other remediation techniques, sustainable remediation practices maximize cost savings while achieving environmental objectives.

Stakeholder Engagement and Community Involvement

- Sustainable remediation practices emphasize stakeholder engagement and community involvement throughout the remediation process, fostering transparency, accountability, and trust.
- By incorporating stakeholder perspectives, local knowledge, and community priorities into remediation decision-making, sustainable practices ensure that remediation efforts are socially acceptable, culturally appropriate, and responsive to community needs and concerns.

Long-term Monitoring and Adaptive Management

- Sustainable bioremediation practices integrate long-term monitoring and adaptive management approaches to assess remediation effectiveness, identify emerging challenges, and adjust remediation strategies accordingly.
- Continuous monitoring of environmental indicators, microbial communities, and contaminant levels allows for early detection of potential issues and timely intervention to prevent setbacks and ensure long-term success.

In conclusion, advancements in bioremediation technologies have profound implications for sustainable remediation practices, offering opportunities to address environmental contamination challenges in a cost-effective, environmentally friendly, and socially responsible manner. By embracing sustainable remediation principles, incorporating innovative bioremediation techniques, and engaging stakeholders collaboratively, we can achieve effective and enduring solutions for restoring contaminated sites, safeguarding ecosystems, and protecting human health for present and future generations.

REFERENCES

1. Adofo, Y. K., Nyankson, E., &Agyei-Tuffour, B. (2022). Dispersants as an oil spill clean-up technique in the marine environment: A review. *Heliyon*, 8(8).
2. Aidarzhanovich, N. A., Bekturovna, Y. Z., Nauryzbaevish, A. S., Beisenbayuly, N., Alaldunkyzy, S. N., Azamat, M., ... &Tureevna, L. Z. (2023). Integrating mathematical analysis and biotechnological approaches for enhanced environmental management. *Caspian Journal of Environmental Sciences*, 21(5), 1185-1201.
3. Ali, M., Song, X., Ding, D., Wang, Q., Zhang, Z., & Tang, Z. (2022). Bioremediation of PAHs and heavy metals co-contaminated soils: Challenges and enhancement strategies. *Environmental Pollution*, 295, 118686.
4. Ambaye, T. G., Vaccari, M., Franzetti, A., Prasad, S., Formicola, F., Rosatelli, A., ... &Rtimi, S. (2023). Microbial electrochemical bioremediation of petroleum hydrocarbons (PHCs) pollution: Recent advances and outlook. *Chemical Engineering Journal*, 452, 139372.
5. Aparicio, J. D., Raimondo, E. E., Saez, J. M., Costa-Gutierrez, S. B., Alvarez, A., Benimeli, C. S., &Polti, M. A. (2022). The current approach to soil remediation: A review of physicochemical and biological technologies, and the potential of their strategic combination. *Journal of Environmental Chemical Engineering*, 10(2), 107141.
6. Awasthi, M. K., Guo, D., Awasthi, S. K., Wang, Q., Chen, H., Liu, T., ... & Zhang, Z. (2020). Recent advances in phytoremediation of toxic metals from contaminated sites: a road map to a safer environment. *Bioremediation of Industrial Waste for Environmental Safety: Volume II: Biological Agents and Methods for Industrial Waste Management*, 77-112.
7. Azuazu, I. N., Sam, K., Campo, P., &Coulon, F. (2023). Challenges and opportunities for low-carbon remediation in the Niger Delta: towards sustainable environmental management. *Science of the Total Environment*, 165739.



**Pooja Kasana and Pankaj Kumar Rai**

8. Basak, G., Hazra, C., & Sen, R. (2020). Biofunctionalized nanomaterials for in situ clean-up of hydrocarbon contamination: A quantum jump in global bioremediation research. *Journal of environmental management*, 256, 109913.
9. Behl, T., Kaur, I., Sehgal, A., Singh, S., Sharma, N., Bhatia, S., ... & Bungau, S. (2022). The dichotomy of nanotechnology as the cutting edge of agriculture: Nano-farming as an asset versus nanotoxicity. *Chemosphere*, 288, 132533.
10. Bora, J., Imam, S., Vaibhav, V., & Malik, S. (2023). Use of Genetic Engineering Approach in Bioremediation of Wastewater. In *Modern Approaches in Waste Bioremediation: Environmental Microbiology* (pp. 485-513). Cham: Springer International Publishing.
11. Cabral, L., Giovanella, P., Pellizzer, E. P., Teramoto, E. H., Kiang, C. H., & Sette, L. D. (2022). Microbial communities in petroleum-contaminated sites: Structure and metabolisms. *Chemosphere*, 286, 131752.
12. Das, M., Patra, P., & Ghosh, A. (2020). Metabolic engineering for enhancing microbial biosynthesis of advanced biofuels. *Renewable and Sustainable Energy Reviews*, 119, 109562.
13. Dhar, K., Subashchandrabose, S. R., Venkateswarlu, K., Krishnan, K., & Megharaj, M. (2020). Anaerobic microbial degradation of polycyclic aromatic hydrocarbons: a comprehensive review. *Reviews of Environmental Contamination and Toxicology Volume 251*, 25-108.
14. Dhar, K., Subashchandrabose, S. R., Venkateswarlu, K., Krishnan, K., & Megharaj, M. (2020). Anaerobic microbial degradation of polycyclic aromatic hydrocarbons: a comprehensive review. *Reviews of Environmental Contamination and Toxicology Volume 251*, 25-108.
15. Dinnukhamed, T., Huang, Z., Liu, Y., Lv, X., Li, J., Du, G., & Liu, L. (2021). Current advances in design and engineering strategies of industrial enzymes. *Systems Microbiology and Biomanufacturing*, 1, 15-23.
16. Gholizadeh, A., & Kopačková, V. (2019). Detecting vegetation stress as a soil contamination proxy: A review of optical proximal and remote sensing techniques. *International Journal of Environmental Science and Technology*, 16, 2511-2524.
17. Häder, D. P., Banaszak, A. T., Villafañe, V. E., Narvarte, M. A., González, R. A., & Helbling, E. W. (2020). Anthropogenic pollution of aquatic ecosystems: Emerging problems with global implications. *Science of the Total Environment*, 713, 136586.
18. Hazen, T. C. (2020). Lessons from the 2010 Deepwater Horizon accident in the Gulf of Mexico. *Hydrocarbons, oils and lipids: Diversity, origin, chemistry and fate*, 847-864.
19. Huang, L., Ye, J., Jiang, K., Wang, Y., & Li, Y. (2021). Oil contamination drives the transformation of soil microbial communities: Co-occurrence pattern, metabolic enzymes and culturable hydrocarbon-degrading bacteria. *Ecotoxicology and Environmental Safety*, 225, 112740.
20. Jia, X., Liu, C., Song, H., Ding, M., Du, J., Ma, Q., & Yuan, Y. (2016). Design, analysis and application of synthetic microbial consortia. *Synthetic and Systems Biotechnology*, 1(2), 109-117.
21. Kour, H., Khan, SS., Kour, D., Rasool, S., Sharma, YP., Rai, PK., Singh, S. (2023). Microbes mediated plastic degradation: A sustainable approach for environmental sustainability. *Journal of Applied Biology and Biotechnology* 11 (3), 9-19
22. Kaya, C., Uğurlar, F., Ashraf, M., Hou, D., Kirkham, M. B., & Bolan, N. (2024). Microbial consortia-mediated arsenic bioremediation in agricultural soils: Current status, challenges, and solutions. *Science of The Total Environment*, 170297.
23. Khatoon, Z., Huang, S., Rafique, M., Fakhar, A., Kamran, M. A., & Santoyo, G. (2020). Unlocking the potential of plant growth-promoting rhizobacteria on soil health and the sustainability of agricultural systems. *Journal of Environmental Management*, 273, 111118.
24. Lin, B., & Ullah, S. (2024). Evaluating forest depletion and structural change effects on environmental sustainability in Pakistan: Through the lens of the load capacity factor. *Journal of Environmental Management*, 353, 120174.
25. Liu, Z., Xu, Z., Zhu, X., Yin, L., Yin, Z., Li, X., & Zheng, W. (2023). Calculation of carbon emissions in wastewater treatment and its neutralization measures: A review. *Science of The Total Environment*, 169356.
26. Mohanram, S., & Kumar, P. (2019). Rhizosphere microbiome: revisiting the synergy of plant-microbe interactions. *Annals of Microbiology*, 69, 307-320.



**Pooja Kasana and Pankaj Kumar Rai**

27. Nwankwegu, A. S., Zhang, L., Xie, D., Onwosi, C. O., Muhammad, W. I., Odoh, C. K., ... &Idenyi, J. N. (2022). Bioaugmentation as a green technology for hydrocarbon pollution remediation. Problems and prospects. *Journal of Environmental Management*, 304, 114313.
28. Nwankwegu, A. S., Zhang, L., Xie, D., Onwosi, C. O., Muhammad, W. I., Odoh, C. K., ... &Idenyi, J. N. (2022). Bioaugmentation as a green technology for hydrocarbon pollution remediation. Problems and prospects. *Journal of Environmental Management*, 304, 114313.
29. Okoh, E., Yelebe, Z. R., Oruabena, B., Nelson, E. S., &Indiamawe, O. P. (2020). Clean-up of crude oil-contaminated soils: bioremediation option. *International Journal of Environmental Science and Technology*, 17(2), 1185-1198.
30. Onyena, A. P., Folorunso, O. M., Nwanganga, N., Udom, G. J., Ekhaton, O. C., Frazzoli, C., ... &Orisakwe, O. E. (2023). Engaging One Health in Heavy Metal Pollution in Some Selected Nigerian Niger Delta Cities. A Systematic Review of Pervasiveness, Bioaccumulation and Subduing Environmental Health Challenges. *Biological Trace Element Research*, 1-34.
31. Pande, V., Pandey, S. C., Sati, D., Pande, V., &Samant, M. (2020). Bioremediation: an emerging effective approach towards environment restoration. *Environmental Sustainability*, 3, 91-103.
32. Patel, H. K., &Makampara, R. A. (2023). Microbial enzymes: a futuristic tools for a sustainable environment in 21st century. In *Emerging Technologies in Applied and Environmental Microbiology* (pp. 45-63). Academic Press.
33. Rabbani, A., Zainith, S., Deb, V. K., Das, P., Bharti, P., Rawat, D. S., ... &Saxena, G. (2021). Microbial technologies for environmental remediation: potential issues, challenges, and future prospects. *Microbe Mediated Remediation of Environmental Contaminants*, 271-286.
34. Rahman, Z., & Singh, V. P. (2020). Bioremediation of toxic heavy metals (THMs) contaminated sites: concepts, applications and challenges. *Environmental Science and Pollution Research*, 27, 27563-27581.
35. Ryan, D. G., Frezza, C., & O'Neill, L. A. (2021). TCA cycle signalling and the evolution of eukaryotes. *Current opinion in biotechnology*, 68, 72-88.
36. Sarkar, J., Roy, A., Sar, P., &Kazy, S. K. (2020). Accelerated bioremediation of petroleum refinery sludge through biostimulation and bioaugmentation of native microbiome. In *Emerging technologies in environmental bioremediation* (pp. 23-65). Elsevier.
37. Sharma, J., Goutam, J., Dhuriya, Y. K., & Sharma, D. (2021). Bioremediation of Industrial pollutants. *Microbial Rejuvenation of Polluted Environment: Volume 2*, 1-31.
38. Sharma, P. (2022). Microbial communication during bioremediation of polyaromatic hydrocarbons. *Systems Microbiology and Biomanufacturing*, 2(3), 430-444.
39. Sharma, P., & Kumar, S. (2021). Bioremediation of heavy metals from industrial effluents by endophytes and their metabolic activity: Recent advances. *Bioresource Technology*, 339, 125589.
40. Silva, I. A., Almeida, F. C., Souza, T. C., Bezerra, K. G., Durval, I. J., Converti, A., &Sarubbo, L. A. (2022). Oil spills: impacts and perspectives of treatment technologies with focus on the use of green surfactants. *Environmental Monitoring and Assessment*, 194(3), 143.
41. Singh, A., Dwivedi, M., & Yadav, H. (2022). Potential of microbes for degradation of xenobiotics: With special focus on petroleum hydrocarbons. In *Relationship Between Microbes and the Environment for Sustainable Ecosystem Services, Volume 2* (pp. 95-118). Elsevier.
42. Sokal, S., Palsania, P., & Kaushik, G. (2022). Bioremediation and functional metagenomics: advances, challenges, and opportunities. *Omics Insights in Environmental Bioremediation*, 3-36.
43. Swapnil, P., Singh, L. A., Mandal, C., Sahoo, A., Batool, F., Meena, M., ... &Zehra, A. (2023). Functional characterization of microbes and their association with unwanted substance for wastewater treatment processes. *Journal of Water Process Engineering*, 54, 103983.
44. TelliKarakoç, F., &Ediger, D. (2020). Oil pollution of the surrounding waters of Turkey.
45. Wartell, B., Boufadel, M., & Rodriguez-Freire, L. (2021). An effort to understand and improve the anaerobic biodegradation of petroleum hydrocarbons: A literature review. *International Biodeterioration & Biodegradation*, 157, 105156.





Pooja Kasana and Pankaj Kumar Rai

46. Wei, Z., Van Le, Q., Peng, W., Yang, Y., Yang, H., Gu, H., ... & Sonne, C. (2021). A review on phytoremediation of contaminants in air, water and soil. *Journal of hazardous materials*, 403, 123658.
47. Yadav, M., Joshi, C., Paritosh, K., Thakur, J., Pareek, N., Masakapalli, S. K., & Vivekanand, V. (2022). Organic waste conversion through anaerobic digestion: A critical insight into the metabolic pathways and microbial interactions. *Metabolic Engineering*, 69, 323-337.
48. Yan, C., Wang, F., Geng, H., Liu, H., Pu, S., Tian, Z., ... & Yao, J. (2020). Integrating high-throughput sequencing and metagenome analysis to reveal the characteristic and resistance mechanism of microbial community in metal contaminated sediments. *Science of The Total Environment*, 707, 136116.
49. Yang, Y., Zhang, Z. W., Liu, R. X., Ju, H. Y., Bian, X. K., Zhang, W. Z., ... & Lu, W. Y. (2021). Research progress in bioremediation of petroleum pollution. *Environmental Science and Pollution Research*, 28, 46877-46893.

Table 1 :Mechanisms of Microbial Hydrocarbon Degradation

Mechanism	Description
Aerobic Degradation	Microorganisms metabolize hydrocarbons in the presence of oxygen, breaking them down into CO ₂ and H ₂ O.
Anaerobic Degradation	Microorganisms metabolize hydrocarbons in the absence of oxygen, utilizing alternative electron acceptors such as nitrates, sulfates, or carbon dioxide.
Hydrocarbon Oxidation	Microorganisms produce enzymes (e.g., alkane monooxygenase, dioxygenase) to oxidize hydrocarbons, initiating degradation pathways.
Hydrocarbon Hydrolysis	Microorganisms produce enzymes (e.g., lipases, esterases) to break down complex hydrocarbons into simpler compounds for degradation.
Biosurfactant Production	Microorganisms produce biosurfactants to solubilize hydrophobic compounds, enhancing their bioavailability for microbial degradation.
Emulsification	Microorganisms form emulsions to disperse hydrocarbons in aqueous environments, facilitating microbial access and degradation.
Co-metabolism	Microorganisms degrade hydrocarbons as secondary substrates while utilizing primary carbon sources for energy metabolism.
Biofilm Formation	Microorganisms adhere to surfaces and form biofilms, providing protection, stability, and metabolic cooperation for efficient hydrocarbon degradation.

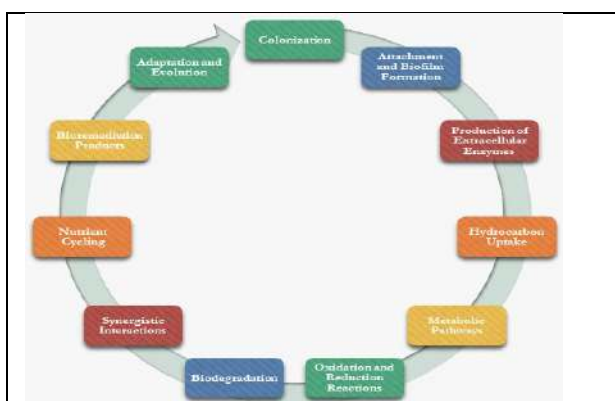


Figure 1 :Mechanisms of microbial bioremediation of oil-contaminated areas



Figure 2 : Challenges and Limitations in Microbial Bioremediation





Performance of Custom Power Devices for Improvement of Power Quality

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ABSTRACT

In order to address the problems with power quality brought on by strong state supplies and devices, this work presents a combined LMS-LMF (least mean square-least mean fourth) with ANFIS (adaptive neuro-fuzzy interference system) based control algorithm for DSTATCOM (Distribution Static Compensator). For comparing dynamic reactive weights and supply reference flows, the combined LMS-LMF based method is designed using MATLAB/SIMULINK 2011a. The suggested control method combines LMS and LMF with adaptive neuro-fuzzy interference system (ANFIS) based control algorithms, enabling rapid and accurate response with a solid strategy. To restrict the error, either LMS-based control or LMF-based control is used, depending on the estimation of the error signal obtained in any of the phases. The newly developed combined LMF-LMS algorithm





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Keywords: DVR, D-STATCOM, power quality disturbance, active voltage conditioner, active power conditioner, and power quality.

INTRODUCTION

SHORT SUMMARY OF POWER QUALITY

Electric power's suitability for use with consumer electronics is determined by power quality. Electrical systems can work as planned without suffering major performance or life losses when the voltage, frequency, and phase are synchronized. The phrase refers to both the amount of electrical power utilized to operate an electrical load and the load's functional capability. An electrical device (or load) may malfunction, fail early, or not perform at all if it is not given the right power. Poor electric power can be produced in a variety of ways, and there are several other factors that contribute to it. The production of electricity (AC power), its transmission, and finally its distribution to an electricity meter installed on the property of the final consumer of the electricity make up the electric power business. The power then travels through the end user's wire infrastructure until it reaches the load. A number of chances exist for the supply's quality to be compromised due to the system's complexity in transferring electric energy from the point of production to the site of consumption as well as fluctuations in the weather, generation, demand, and other variables. While "power quality" is a useful phrase for many, the quality of the voltage, not power or electric current, is what the term properly refers to. Power is just the movement of energy, and a load's required current is generally uncontrolled.

POWER QUALITY DESCRIPTION

The quality of electrical power may be described as a set of values of parameters, such as

- Continuity of service
- Variation in voltage magnitude
- Transient voltages and currents
- Harmonic content in the waveforms for AC power

The tolerance of data-processing equipment to voltage variations is often characterized by the CBEMA curve, which give the duration and magnitude of voltage variations that can be tolerated. Ideally, AC voltage is supplied by a utility as sinusoidal having an amplitude and frequency given by national standards (in the case of mains) or system specifications (in the case of a power feed not directly attached to the mains) with an impedance of zero ohms at all frequencies.

POWER CONDITIONING

- a. An uninterruptible power supply can be used to switch off of mains power if there is a transient (temporary) condition on the line. However, cheaper UPS units create poor quality power themselves, akin to imposing a higher-frequency and lower amplitude square wave atop the sine wave. High-quality UPS units u
- b. A surge protector or simple capacitor or varistor can protect against most overvoltage conditions, while a lightning arrester protects against severe spikes.
- c. Electronic filters can remove harmonics.

DSTATCOM

- a. The new controller system for D-STATCOM (Distribution Static Compensator), which may function as a distributed system while mitigating all failure types.
- b. DSTATCOM is one of the tools for reducing voltage sag in power systems. This study presents a novel way of controlling both balanced and unbalanced voltage sags.
- c. DSTATCOM-based mitigation is suggested. The control system uses two loops to manage the load voltage and the compensator current. cancellation of a delayed signal





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A FLEXIBLE DSTATCOM OPERATING IN VOLTAGE OR CURRENT CONTROL MODE

A distribution static compensator (DSTATCOM) is a voltage source inverter (VSI)-based power electronic device. Usually, this device is supported by short-term energy stored in a DC capacitor. When a D-STATCOM is associated with a particular load, it can inject compensating current so that the total demand meets the specifications for utility connection. Alternatively, it can also clean up the voltage of a utility bus from any unbalance and harmonic distortion. The aim of this paper is to investigate a D-STATCOM that can perform both these tasks. For load compensation using a D-STATCOM, one of the major considerations is the generation of the reference compensator currents. There are several methods that have been developed for the use of the compensator when it tracks these reference currents, thereby injecting three-phase currents in the AC system to cancel out disturbances caused by the load. Most of these methods carry an implicit assumption that the voltage at the point of common coupling is tightly regulated and cannot be influenced by the currents injected by the shunt device. This, however, is not a valid assumption for most applications, and the performance of the compensator will degrade considerably at high-impedance AC connection points. Solace and complex way of life has been on an exponential keep running since the innovation of the strong state devices. The current innovations and the new advancements in strong state types of gear and devices have prompted an extremely serene what's more, smooth life however it builds the power quality issues due to these strong state devices-based burdens. Power quality issues are of real worry in the dispersion system which prompts diminish in effectiveness of the system and a real consideration is to be given to the expanding power contamination. The inexhaustible employments of nonlinear loads, for example, strong state control change devices, medicinal hardware, fluorescent lighting, sustainable power source systems, office and family hardware, HVDC (High Voltage Direct Current) transmission, electric traction, curve heaters, high frequency transformers, and so forth infuse sounds into the system and decrease the nature of energy.

Additionally, because of unequal three phase or single-phase loads, the idea of waveforms in the dissemination system is irritated which in the long run influences the gear and clients close-by. Late research on control quality concentrates on relief of current quality issues like music disposal, control factor redress, stack adjusting, commotion cancelation and voltage quality issues like list, swells, driving forces, voltage unbalances, vacillations and different perspectives. Custom power devices (CPD) i.e., DVR (Dynamic Voltage Restorer), DSTATCOM (Distribution Static Compensator), also, UPQC (Unified Power Quality Conditioner) are contrasting options to relieve propositions current and voltage-based power quality issues. As the current based power quality issues are real worry in the appropriation system because of strong state-based burdens, voltage source converter (VSC) based DSTATCOM is the reasonable innovation or potentially answer for relieve every one of these issues notwithstanding established or existing alleviating innovation like static Var compensators, control capacitors and so on. Different topologies of DSTATCOM have been talked about in the writing and a wide region of research is open to take a shot at the power quality issues. DSTATCOM moreover discovers applications in electric ship control systems, micro grid, circulated era and so on. For the suitable operation of VSC based DSTATCOM, an appropriate control is required. So, one forms algorithm for creating the suitable heartbeats for VSC to overcome the current based power quality issues.

These algorithms are composed either in frequency space or in time area based on the kind of process they create the beats for the devices of VSC. Singh et. al. has very much clarified. Different designs and control algorithms, for example, unit format, PBT(control adjust hypothesis), $I\text{-cos}\phi$, CSD hypothesis (Current Synchronous Detection), IRPT (Instantaneous Reactive Power hypothesis), SRF (Synchronous Rotating Frame) hypothesis, ISC (Instantaneous Symmetrical Components) hypothesis, single PQ hypothesis, single DQ hypothesis, nonpartisan system LMS (Slightest Mean Square) Adaline based control algorithm for DSTATCOM in both PFC (control factor redress) and ZVR (zero voltage control) mode. Singh et. al. have too planned new control for the DSTATCOM with progressed execution with customary algorithm, for example, defective LMS algorithm, composite spectator algorithm, versatile hypothesis based enhanced straight sinusoidal tracer algorithm, SPD (straightforward pinnacle recognition) hypothesis algorithm, back propagation algorithm, Learning-based against Hebbian algorithm, hyperbolic digression work based LMS algorithm, piece incremental met convergence algorithm, and variable overlooking component recursive slightest square algorithm. Every one of these algorithms are intended for ZVR and PFC for the specific system. This is accomplished by separating the reference supply currents from the detected signs of the system and





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after that contrasting them and they watched supply currents to deliver the required heartbeats for the VSC. Luo et. al. has outlined enhanced DPC (coordinate power control) algorithm in light of bum current controller and twofold bum current controller. Kumar et. al. has too outlined the controller for DSTATCOM with enhanced power quality, for example, voltage controlled DSTATCOM, multifunctional DSTATCOM with new control algorithm, enhanced cross breed DSTATCOM topology, intelligent DSTATCOM working in CCM (current control mode) and VCM (voltage control mode). The most recent couple of decades have seen a noteworthy surge in the quantity of specialists chipping away at control quality issues and they have thought of various propellerd control procedures for the sound's concealment, PFC, ZVR, stack adjusting issues and numerous other power quality issues

LITERATURE REVIEW

AN ADAPTIVE CONTROL STRATEGY FOR DSTATCOM APPLICATIONS IN AN ELECTRIC SHIP POWER SYSTEM

Distribution static compensator (DSTATCOM) is a shunt compensation device that is generally used to solve power quality problems in distribution systems. In an all-electric ship power system, power quality issues arise due to high-energy demand loads such as pulse loads. In this the application of a DSTATCOM to improve the power quality in a ship power system during and after pulse loads. The control strategy of the DSTATCOM plays an important role in maintaining the voltage at the point of common coupling. A novel adaptive control strategy for the DSTATCOM based on artificial immune system(AIS) is presented. The optimal parameters of the controller are first obtained by using the particle swarm optimization algorithm. This provides a sort of innate immunity (robustness)to common system disturbances. For unknown and random system disturbances, the controller parameters are modified online, thus providing adaptive immunity to the control system. The performance of the DSTATCOM and the AIS-based adaptive control strategy is first investigated in MATLAB/Simulink-based simulation platform. It is verified through a real-time ship power system implementation on a real-time digital simulator and the control algorithm on a digital signal processor.

ENHANCEMENT OF PV PENETRATION WITH DSTATCOM IN TAIPOWER DISTRIBUTION SYSTEM

The PV penetration level of a distribution system is often limited by the violation of voltage variation caused by large intermittent power generation. This study investigates the use of a distribution static compensator (DSTATCOM) in reactive power compensation for system voltage control, during peak solar irradiation, in order to increase the PV installation capacity of a distribution feeder and avoid the voltage violation problem. PV power generation is simulated using hourly solar irradiation and temperature data provided by the weather bureau. The voltage variation at the point of common coupling (PCC) is also derived by executing the 3- load flow analysis to determine the maximum PV power injection without causing voltage violation. By applying the proposed voltage control scheme of DSTATCOM during high solar irradiation periods, the total power generation and the total energy delivered by the PV system over one year are determined according to the annual duration of solar irradiation. The annual sales of PV power, the system O&M cost, the cost of DSTATCOM installation and the initial capital investment for a PV system are then used to calculate the cash flow over the system life-cycle and the final net present value (NPV) of the PV With the proposed DSTATCOM voltage control to perform reactive power compensation, the optimal installation capacity of PV systems can be determined by maximizing the net present value of the system to ensure the best cost_effectiveness of the PV and to better utilize solar energy.

BACK-PROPAGATION CONTROL ALGORITHM FOR POWER QUALITY IMPROVEMENT USING DSTATCOM

This method presents an implementation of a three-phase distribution static compensator (DSTATCOM) using a back propagation (BP) control algorithm for its functions such as harmonic elimination, load balancing and reactive power compensation for power factor correction, and zero voltage regulation under nonlinear loads. A BP-based control algorithm is used forth extraction of the fundamental weighted value of active and reactive power components of load currents which are required for the estimation of reference source currents. A prototype of DSTATCOM is



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developed using a digital signal processor, and its performance is studied under various operating conditions. The performance of DSTATCOM is found to be satisfactory with the proposed control algorithm for various types of loads.

ENERGY SAVING USING D-STATCOM PLACEMENT IN RADIAL DISTRIBUTION SYSTEM UNDER RECONFIGURED NETWORK

High R/X ratio and significant voltage drop causes substantial power losses along the distribution network. In this method optimal location and size for D-STATCOM is determined for radial distribution networks under reconfigured network to reduce the power loss which in turns save the energy and environment. The main contribution of the method is

- D-STATCOM allocation using index vector method for radial distribution network with and without reconfiguration.
- D-STATCOM size calculation using variation techniques for RDS with and without reconfiguration.
- Impact of CP, CI, CZ, and realistic ZIP load model including load growth on D-STATCOM placement,
- Energy Saving with improvement in voltage profile, reduction in power losses with D-STATCOM placement under reconfigured network.
- Cost analysis with and without D-STATCOM Placement under reconfigured network.
- Results are compared with existing technique proposed in literature. The proposed method is tested for D-STATCOM allocation in IEEE 69-bus radial distribution systems. Results show the considerable improvement in voltage profile, reduction in losses and, energy saving under reconfigured network

POWER QUALITY ENHANCEMENT USING POWER BALANCE THEORY BASED DSTATCOM

The DSTATCOM (Distributed Static Compensator) is used for current harmonic mitigation, Power Factor Correction (PFC), reactive power compensation, load balancing and neutral current compensation in the Power Distribution System (PDS). In this method, the power balance theory based DSTATCOM is used for power quality enhancement like current harmonic mitigation, power factor correction (PFC), reactive power compensation, load balancing and neutral current compensation and load balancing. A non-isolated star/delta transformer is used to reduce dc-link voltage (V_{dc}) of Voltage Source Converter (VSC) and neutral current compensation. The reference source currents can be extracted quickly by using proposed power balance theory. The proposed power balance theory based DSTATCOM is modelled and simulated using MATLAB/SIMULINK under PFC and ZVR (Zero Voltage Regulation) operations

POWER QUALITY

The contemporary container crane industry, like many other industry segments, is often enamoured by the bells and whistles, colourful diagnostic displays, high speed performance, and levels of automation that can be achieved. Although these features and their indirectly related computer-based enhancements are key issues to an efficient terminal operation, we must not forget the foundation upon which we are building. Power quality is the mortar which bonds the foundation blocks. Power quality also affects terminal operating economics, crane reliability, our environment, and initial investment in power distribution systems to support new crane installations. To quote the utility company newsletter which accompanied the last monthly issue of my home utility billing: 'Using electricity wisely is a good environmental and business practice which saves you money, reduces emissions from generating plants, and conserves our natural resources.' As we are all aware, container crane performance requirements continue to increase at an astounding rate. Next generation container cranes, already in the bidding process, will require average power demands of 1500 to 2000 kW – almost double the total average demand three years ago. The rapid increase in power demand levels, an increase in container crane population, SCR converter crane drive retrofits and the large AC and DC drives needed to power and control these cranes will increase awareness of the power quality issue in the very near future.

The power quality can be improved through the following

- Power factor correction
- Harmonic filtering.





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- Special line notch filtering.
- Transient voltage surge suppression.
- Proper earthing systems.

In most cases, the person specifying and/or buying a container crane may not be fully aware of the potential power quality issues. If this article accomplishes nothing else, we would hope to provide that awareness. In many cases, those involved with specification and procurement of container cranes may not be cognizant of such issues, do not pay the utility billings, or consider it someone else's concern. As a result, container crane specifications may not include definitive power quality criteria such as power factor correction and/or harmonic filtering. Also, many of those specifications which do require power quality equipment do not properly define the criteria

POWER QUALITY PROBLEMS

Any power problem that results in failure or misoperation of customer equipment, manifests itself as an economic burden to the user, or produces negative impacts on the environment. When applied to the container crane industry, the power issues which degrade power quality include

- Power Factor
- Harmonic Distortion
- Voltage Transients
- Voltage Sags or Dips
- Voltage Swells

The AC and DC variable speed drives utilized on board container cranes are significant contributors to total harmonic current and voltage distortion. Whereas SCR phase control creates the desirable average power factor, DC SCR drives operate at less than this. In addition, line notching occurs when SCRs commutate, creating transient peak recovery voltages that can be 3 to 4 times the nominal line voltage depending upon the system impedance and the size of the drives. The frequency and severity of these power system disturbances varies with the speed of the drive. Harmonic current injection by AC and DC drives will be highest when the drives are operating at slow speeds. Power factor will be lowest when DC drives are operating at slow speeds or during initial acceleration and deceleration periods, increasing to its maximum value when the SCRs are phased on to produce rated or base speed. Above base speed, the power factor essentially remains constant. Unfortunately, container cranes can spend considerable time at low speeds as the operator attempts to spot and land containers. Poor power factor places a greater kVA demand burden on the utility or engine-alternator power source. Low power factor loads can also affect the voltage stability which can ultimately result in detrimental effects on the life of sensitive electronic equipment or even intermittent malfunction. Voltage transients created by DC drive SCR line notching, AC drive voltage chopping, and high frequency harmonic voltages and currents are all significant sources of noise and disturbance to sensitive electronic equipment

FACTS TECHNOLOG

INTRODUCTION

Power Generation and Transmission is a complex process, wherever power is to be transferred, the two main components are active and reactive power. In a three-phase ac power system active and reactive power flows from the generating station to the load through different transmission lines and networks buses. The active and reactive power flow in transmission line is called power flow or load flow. Power flow studies provide a systematic mathematical approach for determination of various bus voltages, their phase angle, active and reactive power flows through different lines, generators and loads at steady state condition. Power flow analysis is also used to determine the steady state operating condition of a power system. For the planning and operation of power distribution system, Power flow analysis is used. It is very important to control the power flow along the transmission line. Thus, to control and improve the performance of ac power systems, we need the various different types compensators. The continuing rapid development of high-power semiconductor technology now makes it possible to control electrical power systems by means of power electronic devices. These devices constitute an emerging technology called FACTS





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(flexible alternating current transmission systems). The FACTS technology opens up new opportunities for controlling the both types of powers and enhancing the usable capacity of present transmission systems. The possibility that power through a line can be controlled enables a large potential of increasing the capacity of lines. This opportunity is arises through the ability of FACTS controllers to adjust the power system electrical parameters including series and shunt impedances, current, voltage, phase angle, and the damping oscillations etc. The implementation of such equipment requires the different power electronics-based compensators and controllers. The FACTS devices use various power electronics devices such as Thyristors, Gate turnoffs (GTO), Insulated gate bipolar transistors (IGBT), Insulated Gate Commutated thyristors (IGCT), they can be controlled very fast as well as different control algorithms adapted to various situations. FACTS technology has a lot of benefits, such as greater power flow control ability, increased the loading of existing transmission circuits, damping of power system oscillations, has less bed impact on environmental and, has the less cost than other alternative techniques of transmission system is used. The UPFC is one of the most versatile devices. It can not only perform the functions of the static synchronous compensator(STATCOM), thyristor switched capacitor(TSC) thyristor-controlled reactor (TCR), and the phase angle regulator but also provides additional flexibility by combining some of the functions of the above controllers. The main function of the UPFC is to control the flow of real and reactive power by injection of a voltage in series with the transmission line. Both the magnitude as well as the phase angle of the voltage can be varied independently. Real and reactive power flow control can allow for power flow in prescribed routes, transmission lines loading is closer to their thermal limits and can be utilized for improving transient and small signal stability of the power system.

FACTS CONTROLLER

Flexible AC Transmission System (FACTS): Alternating current transmission systems incorporating power electronic-based and other static controllers to enhance controllability and increase power transfer capability. The various basic applications of FACTS-devices are

- a. Power flow control
- b. Increase of transmission capability
- c. Reactive power compensation
- d. stability improvement Power
- e. quality improvement
- f. Power conditioning

The classification of FACTS Controllers Based on power electronic devices. In left hand side column of FACTS-devices employs the use of thyristor valves or converters. These valves or converters are well known since several years. They have lows witching frequency and low losses. The devices of the right- h a n d side column have more advanced technology of voltage source converters based mainly on Insulated Gate Bipolar Transistors(IGBT)or Insulated Gate Commutated Thyristors(IGCT).Pulse width modulation technique is used to control the magnitude and phase of the voltage. They have high modulation frequency.

SCHEMATIC DESCRIPTION DISTRIBUTION SYSTEM WITHDSTATCOMWITHLMS-LMFBASED CONTROL ALGORITHM

The power quality in the distribution system can be improved by using the proposed configuration. This system includes a three-phase nonlinear load which is supplied from a 415 V,50 Hz, 3-phase AC supply with supply resistance (R_s) and supply inductance (L_s), VSC with a DCbus capacitor (C_{dc}) and ripple filters (R_f, C_f) to eliminate the high switching frequency noiseduring the operation of VSC. The VSC is linked to the Point of Common Coupling (PCC) through the interfacing inductors(L_i)which are tuned such that they reduce the ripples in the compensating currents. A 3-phase diode bridge rectifier (DBR) is used as a nonlinear load with aRL branch on the DC side. For the simulation filters (R_f and L_f) and interfacing inductors (L_i) are redesigned considering the specifications of three phase PCC voltage at415 V and the load to operate at 20kW power rating.





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AN ADAPTIVE NEURO-FUZZY INFERENCE SYSTEM

An adaptive neuro-fuzzy derivation network or versatile system based fuzzy deduction network (ANFIS) is a sort of counterfeit neural system that depends on Takagi–Sugeno fuzzy induction network. Its induction network compares to an arrangement of fuzzy IF–THEN decides that have learning capacity to inexact nonlinear capacities. Thus, ANFIS is thought to be an all-inclusive estimator. For utilizing the ANFIS as a part of a more productive and ideal way, one can utilize the best parameters acquired by hereditary calculation. ANFIS: Artificial Neuro- Fuzzy Inference Systems

- ANFIS are a class of adaptive networks that are functionally equivalent to fuzzy inference systems.
- ANFIS represent Sugeno e Tsukamoto fuzzy models.
- ANFIS uses a hybrid learning algorithm.

In the field of manmade brainpower neuro-fuzzy insinuates blends of fake neural frameworks and fuzzy ethod of reasoning. Neuro-fuzzy hybridization achieves a cream keen system that synergizes these two methods by joining the human-like considering style fuzzy systems with the learning and connectionist structure of neural frameworks. Neuro-fuzzy hybridization is generally named as Fuzzy Neural Network (FNN) or Neuro-Fuzzy System (NFS) in the composition. Neuro-fuzzy system (the more standard term is used from this time forward) wires the human-like considering style fuzzy systems utilizing fuzzy sets and a semantic model containing a course of action of IF-THEN fuzzy gauges. The essential nature of neuro-fuzzy systems is that they are boundless approximates with the ability to ask for interpretable IF-THEN standards. The nature of neuro-fuzzy systems incorporates two clashing necessities in fuzzy showing: interpretability versus precision. For all intents and purposes, one of the two properties wins. The neuro-fuzzy in fuzzy exhibiting research field is isolated into two zones: semantic fuzzy showing that is fixated on interpretability, generally the Mamdani display; and correct fuzzy showing that is revolved around precision, fundamentally the Takagi-Sugeno-Kang (TSK) demonstrate. Speaking to fuzzification, fuzzy surmising and de-fuzzification through multi-layers encourage forward connectionist systems. It must be called attention to that interpretability of the Mamdani- sort neuro-fuzzy frameworks can be lost. To enhance the interpretability of neuro-fuzzy frameworks, certain measures must be taken, wherein imperative parts of interpretability of neuro-fuzzy frameworks are additionally talked about. A current research line tends to the information stream mining case, where neuro-fuzzy frameworks are consecutively refreshed with new approaching specimens on request and on-the-fly. Subsequently, framework refreshes don't just incorporate a recursive adjustment of model parameters, yet in addition a dynamic development and pruning of model to deal with idea float and powerfully changing framework conduct sufficiently and to keep the frameworks/model's "avant-garde" whenever.

RESULTS AND DISCUSSION

SIMULATION RESULTS ANALYSIS

SIMULATION MODEL FOR DISTRIBUTION SYSTEM WITH D-STATCOM

The simulation model of appropriation system with DSTATCOM utilizing the combined LMS-LMF based control algorithm is produced by utilizing MATLAB programming. The display is keep running in both PFC and ZVR modes under nonlinear stack. The consistent state and dynamic exhibitions for the proposed consolidated LMS-LMF based control algorithm are considered in detail.

INTERMEDIATE SIGNALS FOR COMBINED LMS-LMF BASED ALGORITHM

The characteristics of intermediate signals for the combined LMS-LMF based DSTATCOM and ANFIS under nonlinear load. In waveforms of PCC voltages(v_{pcc}), phase 'a' current of supply (isa), phase 'a' current of load(iLa), average value of the active weight component in-phase to supply voltages (awa), total active weight component (was), average value of reactive weight components in-quadrature to supply voltages (wr), total reactive weight component (wrs), supply currents (is) and reference supply currents (is^*) are shown. These waveforms from 0.52 s to 0.54 s are during unbalanced load by switching off the phase 'a' of load. At 0.54s, the phase 'a' of load is reconnected. Since the overall load is reduced between 0.52 s and 0.54 s, the value of weights is less but as the load is reconnected at 0.54 s, the weights built back to their higher value while the actual and reference supply currents are sinusoidal and balanced.





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DYNAMIC RESPONSE OF SYSTEM IN ZVR MODE

The dynamic response of the system in the ZVR mode for a varying load is shown in Fig.6. In the figure, waveforms of PCC voltages (v_{pcc}), supply currents (i_s), load currents (i_{La} , i_{Lb} , and i_{Lc}), compensator currents (i_{ca} , i_{cb} and i_{cc}), DC voltage across the VSC (v_{dc}) and voltage amplitude at PCC (V_t) are shown. One may see that when the phase 'a' load is cut off, the supply currents are sinusoidal and balanced. Moreover, the DCLink voltage is regulated at 700 V and the AC PI controller regulates the PCC voltage amplitude at a nominal value of 338.8 V even during load unbalanced condition.

CONCLUSION

The proposed combined LMS-LMF based control algorithm using ANFIS controller of DSTATCOM has been executed and simulated for both ZVR and PFC modes under nonlinear balanced and unbalanced loads. In addition, this algorithm has likewise been checked on the equipment model of the DSTATCOM created in the MATLAB. The proposed algorithm has been utilized for acquiring the reference supply currents from the dynamic and responsive weight segments with bends of the PCC voltages and supply currents well beneath 5% which is well inside the predetermined standard. The heap adjusting has likewise been accomplished keeping the waveforms of PCC voltages and currents as sinusoidal and in stage. Comparing the results for both LMS-LMF based PI controller and ANFIS controller. LMS– LMF based ANFIS controller gives the better results.

REFERENCES

1. Yan, Chen & Wang, Peng & Pang, Haitian & Sun, Lifeng & Yang, Shiqiang. (2017). CELoF: Wi-Fi Dwell Time Estimation in Free Environment. 10132. 503-514. 10.1007/978-3-319-51811-4_41.
2. Singh, Isha & Sigg, Stephan. (2017). Smart City Environmental Perception from Ambient Cellular Signals. 695-704. 10.1007/978-3-319-65482-9_55.
3. Angelova, Liliya & Flikweert, Puck & Karydakakis, PanagIoTis & Kersbergen, Daniël & Teeuwen, Roos & Valečkaitė, Kotryna. (2017). 148 DynamIoT - Geomatics Synthesis Project on IoT. 10.13140/RG.2.2.22116.27528.
4. M. Griego, Danielle & Buff, Varin & Hayoz, Eric & Moise, Izabela & Pournaras, Evangelos. (2017). Sensing and Mining Urban Qualities in Smart Cities. 10.1109/AINA.2017.14.
5. Fernández Ares, Antonio & Mora, Antonio & Arenas, M.G. & GarcíaSánchez, Pablo & Romero, G & Rivas Santos, Victor & Castillo, Pedro & Merelo Guervós, Juan. (2016). Studying real traffic and mobility scenarios for a Smart City using a new monitoring and tracking system. Future Generation Computer Systems. 76. 10.1016/j.future.2016.11.021.
6. Nazari, Mohamad Esmail. (2018). Smart Grid Unit Commitment with Considerations for Pumped Storage Units Using a Heuristic Optimization Algorithm.
7. Bracco, Stefano & Delfino, Federico & Ferro, Giulio & Pagnini, Luisa & Robba, Michela & Rossi, Mansueto. (2018). Energy planning of sustainable districts: Towards the exploitation of small size intermittent renewables in urban areas. Applied Energy. 228.2288- 2297.10.1016/j.apenergy.2018.07.074.
8. Strasser, Thomas & Siano, Pierluigi & Ding, Yi. (2018). Methods and Systems for a Smart Energy City. IEEE Transactions on Industrial Electronics. 66. 1363-1367. 10.1109/TIE.2018.2869488.
9. Dominković, Dominik. (2018). Modelling Energy Supply of Future Smart Cities. 10.11581/dtu:00000038. 149
10. Guan, Zhitao & Si, Guanlin & Zhang, Xiaosong & Wu, Longfei & Guizani, Nadra & Du, Xiaojiang & Ma, Yinglong. (2018). Privacy-preserving and Efficient Aggregation based on Blockchain for Power Grid Communications in Smart Communities.





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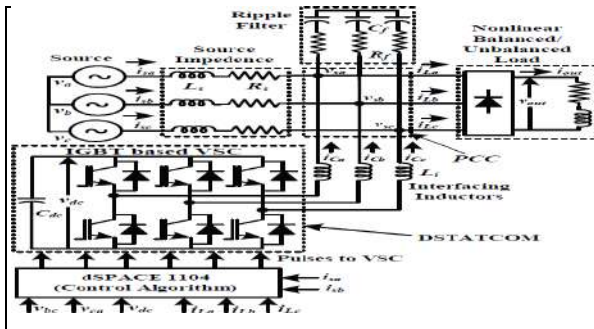


Fig 1: schematic diagram of distribution system with DSTATCOM

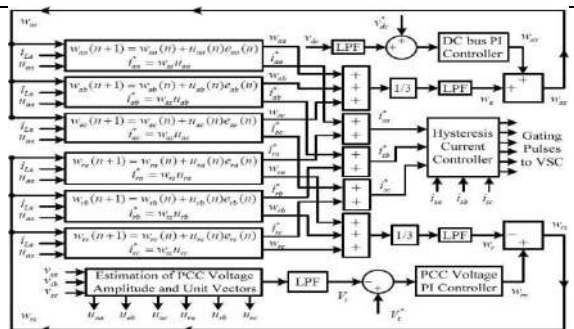


Fig 2: Block diagram of combined LMS-LMF based control algorithm

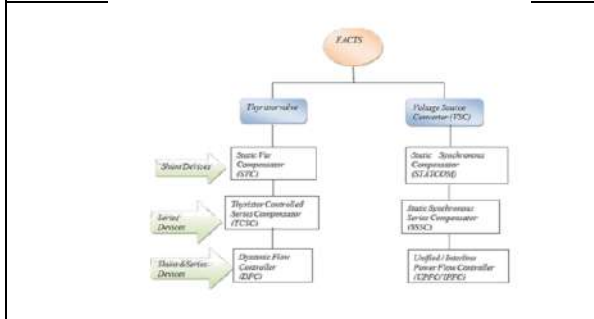


Fig 3: Overview Of major FACTS devices in terms of power electronic devices

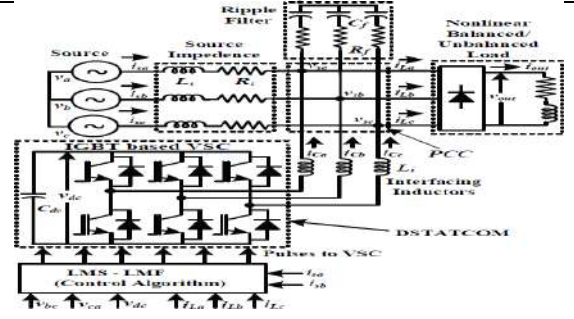


Fig 4: Schematic diagram of distribution system with DSTATCOM with LMS-LMF based control algorithm

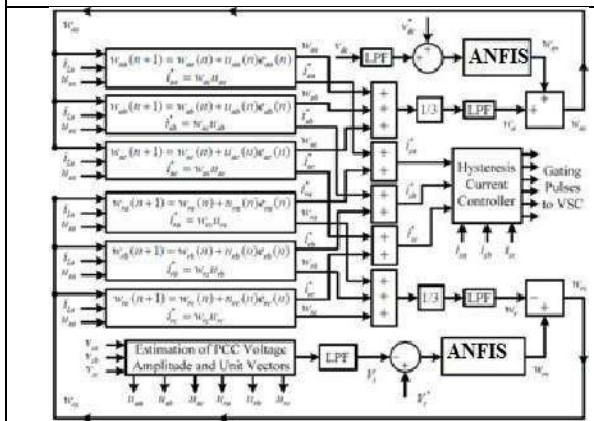


Fig 5: Block diagram of combined LMS-LMF based ANFIS control algorithm

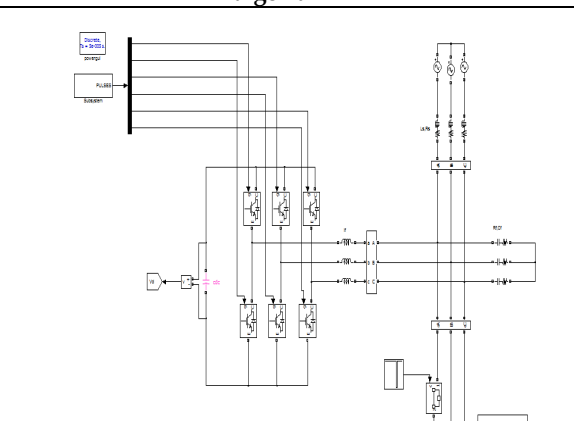


Fig 6: Simulation Model for Distribution System With D-STATCOM



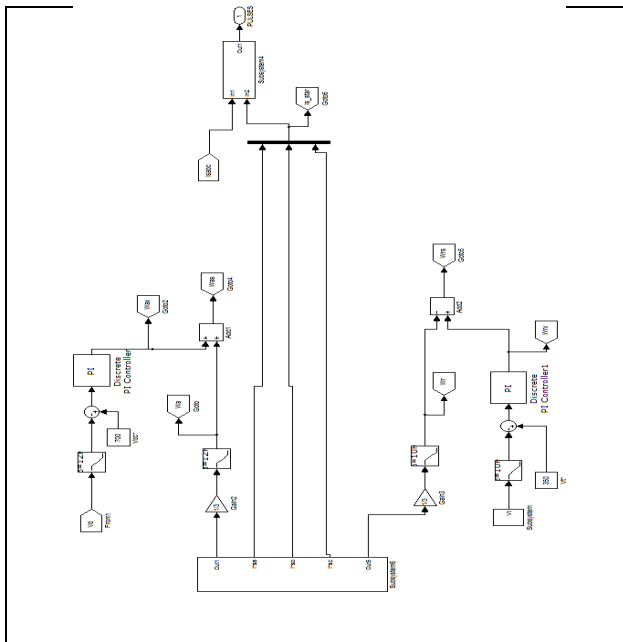


Fig 7: Simulation Model for Distribution System With D-STATCOM Using PI controller

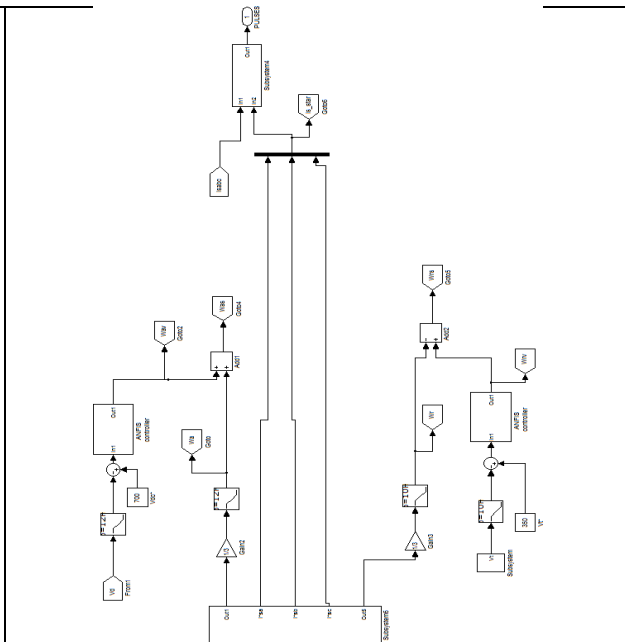


Fig 8: Simulation Model for Distribution System With D-STATCOM Using ANFIS Controller

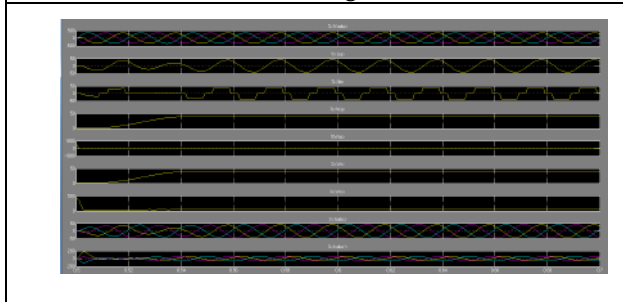


Fig 9: Characteristics Of Intermediate Signals for Combined LMS-LMF Based Algorithm DSTATCOM

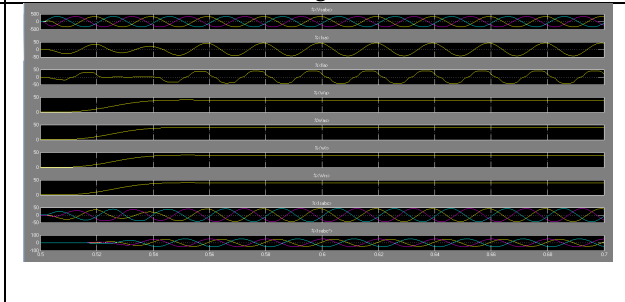


Fig 10: Characteristics Of Intermediate Signals for Combined LMS-LMF Based Algorithm DSTATCOM with ANFIS

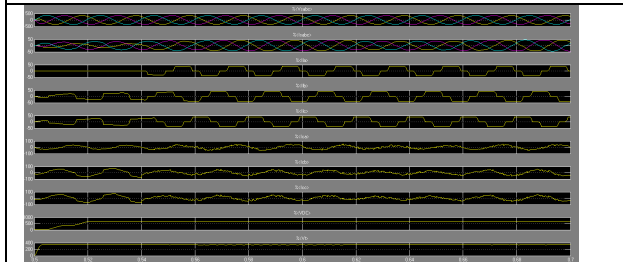


Fig 11: Dynamic response of system in ZVR mode

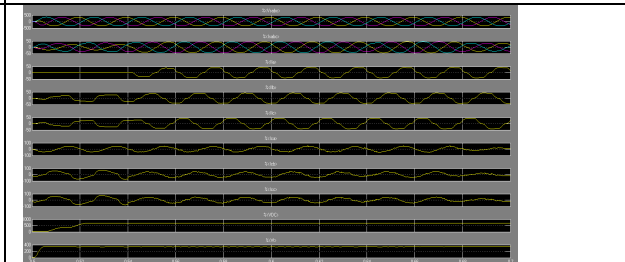


Fig 12: Dynamic response of system in ZVR mode with ANFIS





A Case Study of Vamana Karma Followed by Shaman Aushadhi in The Management of Ekakushtha w.s.r. to Psoriasis

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ABSTRACT

In *Ayurveda* all the skin diseases have been discussed under the 'Kushtha'. *Ekakushtha* is a type of *KshudraKushtha*. In *VyaadhiKshudraKushtha*, it does not cause any major systemic involvement but their appearance disturbs mental condition of the patient as the disease doesn't leave patient easily. Recurrence rate of this disease is very high and it is not easy to treat. The clinical feature of *Ekakushtha* described represents remission, relapse and seasonal variation which are also present in Psoriasis. Modern medical science treats Psoriasis with PUVA, corticosteroids etc. But these therapies give serious side effects like hepatic and nephrotoxicity, bone marrow depression etc. Hence, it is the need of time to find out safe and effective treatment for Psoriasis and here *Ayurveda* plays an important role. Treatment modality of *Ayurveda* provides long lasting results and a better life to patients through its three basic principles i.e. *Shodhana*, *Shamana* and *Nidan Parivarjana*. Here we are reporting a 21- year male patient having symptoms of *Ekakushtha* since last 1.5 years. He was suffering from large round erythematous scaly patches over his Chest and low back region and elbow joint and also severe itching and dryness over affected lesions. There was no such significant past history of any other chronic illness. The patient was treated with *Panchkarma*. *Vamana karma* followed by Oral medications. Patient reported symptomatic improvement after the course of *Vamana Karma*.

Keywords: *Vaman, Madanaphala Kashaya Yoga, Ekakushtha, Shodhana, Psoriasis, Bio-Purification,*





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INTRODUCTION

Human skin is considered, as the largest organ of the integumentary system, it is also the vehicle for the biological and social communication to the external world. Skin reflects our emotions and some aspects of normal physiology. Any deformity or disease condition of the skin leads to both physiological and psychological disturbance of the patient.[1] Nowadays skin disease is very common. It is more prevalent in tropical and subtropical countries like India where the heat and humidity are high for most part of the year. It is too common and easy to underestimate the impact of skin diseases in patients. In most person healthy skin plays a major role and is a key component of the image they present to the outside world. Conversely those with skin disease are often stigmatized, due to appearance they belief is a result of a contagious disease. [2] Nowadays consumption of junk food, fast food, cold drinks, smoking and drinking alcohol are increasing. There is a development of metabolic disorders like heart disease, diabetes mellitus, Renaldisease, and skin disease. Among these, Skin diseases can adversely affect almost every aspect of person's life. It may lead the person to have low-esteem, depression and embarrassment. The name *Panchkarma* literally means "Five Actions" namely *Vamana* (Emesis), *Virechana* (Purgation), *Niruha*(therapeutic decoction enema) *Anuvaasana* (therapeutic oily Enema) and *Nasyam* (therapeutic errhine). In other words, *Panchakarma* is a healing technique or a pillar on which majority of *Ayurvedic* techniques stand. In *Ayurveda* all the skin diseases have been discussed under the *Vyadhi"Kushtha"* *Ekakushtha* (Psoriasis) is one among *Kshudra-Kushtha*. Nearly all *Acharyas* have described *Ekakushtha* first in their 11 types.

Symptoms of *Ekakushtha* are

Aswedanam (Absence of Perspiration), *Mahavastu*(Large area), *Mandaloutpati* (Patches), *Rukshata* (Dryness), *Matsyashakalopamam* (silvery scales). *Ekakushtha* (Psoriasis) has dominancy of *Kapha-Vata Doshas*[3]. So clinically it can be correlated with Psoriasis. Psoriasis is a skin disease which affects the 0.44 - 2.8% of the Indian population. Treatment of Psoriasis may fall in 3 categories- Topical applications, systemic medications and Light therapy[4].But, these treatments come with lots of side effects, such as joint pain, hair loss, loss of appetite, kidney damage and the major one is Carcinoma. Here *Ayurveda* plays an important role, i.e. *Ekakushtha* being *Kapha- Vata Pradhana*, *TridoshajaVyadhi* is best treated by *Shodhan* procedure[5]. *ShodhanaChikitsa* forms the mainstay of treatment for all major skin diseases in *Ayurveda* which helps to remove the deep-seated *Dosha's* from the root itself. Here in this study *Vamana Karma* is planned because it helps to eliminate deep seated *Dosha* from the body. In *Ayurveda* line of treatment both *Shamana* and *Shodhana* are available. As *Ekakushtha* is *BahudoshajaVyadhi*, *Punah -PunahShodhana* can be done to avoid recurrence.[6]

MATERIALS AND METHODS

Case Study

A 21-year-old male patient registered by the O.P.D. number 158 on the date of 03/01/2022 came to the O.P.D. no. 07 of Sanjeevani Ayush Chikitsalaya of Post Graduate Institute of Ayurvedand got admitted in *Panchakarma* Department, with IPD number 21. He presented herself with the following complaints,

- Scaly Patches (*Matsyashakalopamam*) over Chest, Back and B/L elbow joint with red demarcation with *Mandalotpatti*.
- Severe itching, which would rarely result into bleeding.
- Dryness.
- Suffering from the last 1.5 years.
- Had taken modern treatment with limited improvement and recurrence.

Associated complaints- Irregular evacuation of stools.

Past History

- No H/O- DM, HTN, Surgical Procedures.





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- No F/H/O- Any skin disorder

On Examination

- General condition: Moderate
- Pulse rate: 78/min
- B.P: 124/76 mm of Hg
- R.R: 14/min
- H.R: 74/min

Astha SthanaParikshna

1. **Nadi:** Vata-Kaphaj
2. **Mala:** Normally formed stools, sometimes hard stools
3. **Mutra:** Prakrita
4. **Jivha:** Sama, Lipta
5. **Shabda:** Prakrita
6. **Sparsh:** Mridu
7. **Drika:**Prakrita
8. **Akriti:**Madhyama

Systemic examination

- Respiratory System: B/L Chest clear, Airway entry, Breathing entry Clear
- Cardiovascular System: - S1 S2 heard.
- CNS: All superficial reflexes are intact. Patient is conscious and well oriented.
- GIT: Soft Abdomen, Bowel sound heard, No Pain or any other symptoms

Skin examination

Chief Complaints

- Aswedanam- Absent
Mahavastu(area)- Present (++)
Matsyashakalopam- Present (+++)
Kandu- Present (++++)
Pidaka- Absent
Daha- Absent
Vaivarnya- Present (+++)
Rukshata- Present (+++)

History of Present Illness

Onset- Gradual

Chronicity- Chronic

Course- Progressive

Provoking Factor- Winter

Relieving Factor- Sunlight

- Shape - Irregular Scaly Patches
- Size - Multiple Patches, no specific size. (Ranging from 7mm to 5 cm too)
- Site- B/L knee joint and elbow joint
- Auspitz sign - 2
- Candle grease sign - 1





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- PASI Score – 25.8^[7]

Samprapti Ghatak

- *Dosha- Kapha Pradhana Vata Anubandhi*
- *Dushya- Rasa, Rakta, Mamsa, Ambu*
- *Srotas- Rasavaha, Raktavaha, Mamsavaha, Svedavaha*
- *Strotodushiti- Sanga*
- *Ama- Sama*
- *Udbhavasthana- Amashaya*
- *Vyaktisthana- Chest, Back and elbow joints.*

Treatment protocol

After proper clinical examination, patient was diagnosed with *Ekakushtha* and was advised to undergo *Vamana Karma*. i.e.

Purva Karma

- **Deepana Pachana:** *PanchkolaChoorna* -5 gms twice a day, before food with luke warm water was given until *Nirama Lakshana* appears, there after the patient was given *Snehapana*.
- **Snehapana:** *Snehapana* with *Go-Ghrita* given to the patient in increasing dose pattern, until *Samyak Snigdha Lakshana* appears, i.e. from 06/01/2022- 12/01/2022 *Snehapana* administered and daily *Jiryamana* and *Jirna Lakshana* of *Snehapana* noted. (As shown in Table-1)
- **Vishrama Kala:** On 13/01/2022, *Abhyanga* with *MurchitaTila Tail* followed by *Nadi Sweda* was done for 1 day and *Kaphautkleshta Ahara* was given to the patient in the evening.
- **Pradhana Karma:** *Vamana Karma* with *MadhanphalaPippali Kashaya Yoga* administered to the patient, i.e. On 14/01/2022, *Vamana Karma* day, first *Abhyanga* with *MurchitaTila Taila* and *Ushna Jala Snana* was given to the patient. The patient was told and counselled regarding the procedure and Patient sign was taken on informed Consent Form.

At first Blood Pressure (124/82 mm of Hg) and Pulse Rate (78/min) was monitored. Then *Yavagu* (80 to 120 gm) was given to patient just after the bath at 6.55AM (*Akshudhitaavastha*), afterthispatient was made to take luke warm Milk – 2 ltr (*Akanthapana*) at 7:08AM. At 7.16 AM, *VamanaYoga* or Medicine was given to patient in *Kashaya* form, i.e. *Madhanphalapipalli (Antar-nakha-musti-parmana)* = 9 gm, *Yastimadhukashya* = 100 ml *SaindhavaLavana* = 1 gm and Honey = Quantity sufficient. The patient was observed until the appearance of 1st *VamanaVega*, then 2 ltrsof *Yastimadhuphantawas* given from 7:41 AM and after this, 2 ltrsof *Lavanodakawas* given to patient from 7:56 AM. After the completion of *Vaman Karma Dhoompana* with *Haridradivarti* was given at 8:25AM. A Chart was maintained to note down Time of starting of Vegas, contents etc. in theformat (As Shown in Table-2).

Paschat Karma

SamsarjanaKrama advised as per *Shuddhi* attained, i.e. *Samsarjana karma* for 7 days wasadvised to the patient, which contains 12 *Anna Kala*. In 1st to 3rd *Annakala Peya* was advised. Gradually *Ahara* was changed (*Laghu to Guru Guna Pradhana*), finally normal diet was given in the evening of 7th day. After that patient was advised discharge and *Shamanaushadhi* was given (As shown in Table-3)

OBSERVATIONS AND RESULT

Observations on Vamana Karma

1st *Vega* starts at 7:13 AM, last *Vega* i.e. 9th *Vega* was observed at 8:02 AM. Depending upon observation done during the whole procedure below findings were noted (As shown in Table-4)





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Observations on Signs and Symptoms

- **Gradation Scales of Different Symptoms-** As shown in Table-5
- **CANDLE GREASE SIGN & AUSPITZ SIGN-**

Score – 0, 1, 2 for Absent, Improving, Present respectively.

On the Basis of Result found during treatment, observations were quoted below as mentioned in Table-6 and as shown in Image – 1, 2, 3 & 4.

DISCUSSION

Psoriasis is a Papulo Squamous disorder of the skin, characterized by sharply defined erythematous squamous lesions. They vary in size from pinpoint to large plaques. At time, it may manifest as localized or generalized Pustular eruption^[8]. *Eka-Kushtha* can be compared with Psoriasis, because the description and characteristic feature of it are similar with description of Psoriasis, i.e. *Aswedanam* (Absence of perspiration) - The lesion of this disease are dry & rough, *Mahavastu* (Large area) - Lesions are found all over the body, *Matsyashakalopamam* (Scaly patches) - Well-defined raised macules, papules, erythematic plaques which are covered with silvery scales. *Krishna Aruna varna* (erythematous lesion). It is counted as *Kshudrakushtha*[9]. As it is a disease of *BahyaRogamarga*, so both *Antahparimarjana* (Internal) and *Bahirparimarjana* (External) treatments should be used. Considering the above facts, composite treatment plan was adopted. Initially *AbhyantaraShodhana* (Internal oleation) done with *Vamana Karma* and after completion of *Samsarjana Krama* (Dietary), *Samshamana* treatment was advised.

- **Purva karma-** The *Purva Karma* administered in the form of *Deepana-Pachana* and *Snehapana*. *Purvakarman* has the important action of separating the vitiated *Doshas* from the *Dushyasi*. i.e. *Srotasin* the body (*Dosha-Dushya samurchana*). It also helps in bringing the vitiated *Dosha* from *Shakhato* the *Koshtha* area in the body from where these vitiated *Dosha* can be removed from the nearest root of the body. [10]
- **AbhyantraSnehapana:** *AbhyantaraSnehapana* (internal oleation) is the process of administration of *Sneha* internally employed for the purpose of *Shodhana*, *Shamana* and *Brimhana*. It is important here to understand the signs and symptoms of *SamyakaSnehana* described by *Acharyas* i.e. *Snehana* indicates *Snigdhatva* (unctuousness), *Vishyandan* (liquefaction), *Vilayana* (dissolution or diffusion) *Dalhanacharya* while commenting quotes *Vishyandanam Drava Srutilhi*, *Mardavata* means softness. *Kleda* is moistness or wetness. Here *Kleda* signifies the increase of *Apya Guna* in the body^[11]. Considering these *Gunas* as the primary features the assessment of *SamyakSnigdha* is done. *Sneha* can be considered by the unctuousness of the body, stool and skin (*PureshaTwak* and *Gatra Snigdhatva*). *Vishyandana* is witnessed by excretion of stool with or without *Sneha*, (*Snigdha Mala* and *AdhastatSnehadarsana*). *Mardavata* is assessed by *Gatra Mardava*. *Kledana* is assessed by consistency of stool i.e. *AsamhatVarcha*[12].

The *Doshas* present in the body has its own *Gati*, and in *Vyadhita Avastha* the *Doshas* will be aggravated and may be present in *Shakhas* (periphery). The *ShodhanaChikitsa* (Purification) aims at expulsion of this vitiated *Doshas* from the body either by *Urdhwamarga* (administering *Vamana*) or *Adhomarga* (administering *Virechana*) [13]. *Acharya Vagbhata* in *Doshopakramaniya* has explained the causes for *Dosha Gati*. *Vyayama* (exercise), *Ushma* and *Tikshnata* of *Jataragni* (Digestive fire), *Ahita Ahara Bhojana*, vitiates the *Vatadi Doshas* and takes the *Doshas* to *Shakhas* from *Koshtha*. These *Doshas* are brought back to *Koshtha* by *SrotomukhaVishodhana* / *Vivarana*, *Abhishyandi* / making *Dosha Dravibhuta*, *Paaka* (bringing *Pachana* of the *Dosha*), which is well delivered by *Snehana* and *Swedana Karmas*[14]. For the attainment of *Shodhanaphala* proper *Snehapana* is an essential factor which is directly dependent on *Agni* and *Agnibala* as a prime factor. Thus, assessing *Agni* is very essential before *ShodhanarthaAbhyantaraSnehana*. [15]

Pradhan karma

Vaman was performed as a *Pradhana Karma* here. Because *Ekakushtha* being *Kapha Pradhana*, *Tridoshajavyadhi* best treated by *Shodhana* procedure. Soothened *Doshas* will get liquefied and reaches to *Koshtha* by *Swedana*, which can be





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easily eliminated by the action of *Vamana Shodhana* (*Vamana* and *Virechana*) probably may leads to certain endogenous changes in the body responsible for the alleviation of psoriatic pathological process.

Samsarjanakrama

Samsarjan krama was carried out in the patient for 7 days 12 *Annakala* considering the *Pravara Shuddhi* (Best *Shuddhi*). Due to *ShodhanAgni* got hampered So *Samsarjana krama* enhances *Agni* as well as provide strength to the body after *Vamana*^[6]. Hence the patient was kept on *Laghu, Pathyahar* and discharged.

Internal Medications

PanchatiktaghritGuggulu

This is a very potent drug of choice in *KushthaAdhikar*. It is indicated in *Visham* and *Atiprabala Vata*. *Nimba, Guduchi, Patola, Kantakari, Vasa* are the contents of *Panchtikta*. Here in Psoriasis though *Kapha* and *Vata* are involved, to spread all these *Doshas* are carried by *Vata* itself. *Tikta Rasa* acts on both *Vata* and *Kapha Doshas*. *Guggulu* is *Yogavahi Dravya*. Acts as Anti Itching property, *Kleda, VikrutaMeda Upshoshana, Vranashodhaka* (wound healing).[17]

Arogyavardhani Vati

It is herbomineral formulations. It is having *Kushtahara, Durmedahara, Kledahara, Dhatu Gata Amapachana, Raktaprasadana*, and also having *Deepana-Pachana* and *Kapha-Vata Shamaka* property, all these qualities are very much helpful for *SampraptiVighatan* of *Kushtha*. [18]

Gandhakrasayan

It is having properties like *Kushtagna, Rakta Doshahara, Vishaghna, Vranasodhana, Ropana, Rakta-Tvakgata Vishahara, Durmedhohara, Rasayana, Dhatubalya*. all these properties are essential to treat *Ekakushtha*.

Manjistadikashayam

This medicine is mainly used in treatment of various skin diseases. It also helps in natural purification of blood so can be used in skin related problems. *ManjishyadiKashayam* helps in blood detoxification and also dissolves the obstructions in blood flow.

CONCLUSION

From this case report we may conclude that combined *Ayurvedic* treatment and diet regimen can be potent and effective in treatment of *Ekakushtha* (Psoriasis). No adverse effect and aggravation of the symptoms was found in the patient during and after the treatment. The complete study with a larger sample size can be done to check the significant result on the disease as well as the *Karma*. *Ekakushtha* is a chronic and relapsing in nature, *Acharya* mentioned *PunahPunahShodhana* (Repeated Purification) for treating *Kushtha*, Hereafter *Vamana Karma* other *Shodhana* therapy like *Virechana, Raktamokshana* can be followed for better results.

REFERENCES

1. Davidson's. Principles and practice of medicine. 21st edition. Churchill living stone publication, 2010, Chapter – (Diseases of the skin) Pg-900.
2. Michael Hertl; Autoimmune diseases of skin; third edition; Springer Wein New York; pg. no. 328-331.
3. Pandit Kashinath Pandey and Gorakhnath Chaturvedi; Charak Samhita, SavimarshaVidyotini- Hindi Vyakhya; Varanasi; Ed 2011; Pub Chaukhamba Sanskrit Sansthanachikitsa sthan.7.Pg no117
4. Sunil Dogara, Psoriasis: Epidemiology, Clinical features, Co-morbidities, and Clinical scoring, Indian dermatology online journal, 1 Nov 2016, Pg no:471-480





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5. Pandit Kashinath Pandey and Gorakhnath Chaturvedi;Charak Samhita Chikitsa sthan.7, Savimarsha Vidyotini-Hindi Vyakhya;Varanasi; Ed 2011;Pub-Chaukhamba Sanskrit Sansthana.Pg no.712
6. Pandit Kashinath Pandey and Gorakhnath Chaturvedi;Charak Samhita. ChikitsaSthan.7, Savimarsha Vidyotini-Hindi Vyakhya;Varanasi; Ed 2011;Pub-Chaukhamba Sanskrit Sansthana.
7. PASI Calculator- <http://pasi.corti.li/>
8. Neena Khanna; Illustrated synopsis of Dermatology and Sexually transmitted diseases; Ed 2005; Peepee publishers and distributors; Pg. no. 38.
9. Pandit Kashinath Pandey and Gorakhnath Chaturvedi;Charak Samhita Chikitsa sthan.7, Savimarsha Vidyotini-Hindi Vyakhya;Varanasi; Ed 2011;Pub-ChaukhambaSanskritSansthana.
10. Vasant C patil; Principles and practices of Panchakarma, chapter-7. Publication- Chaukhambha Sanskrit Sansthana. Pg no 104.
11. Sushrut Samhita, edited by Ayurved Tattva Sandipika,by Ambika Dutta Shastri,Chaukhamba Sanskrit Sansthan, Varanasi,part 1,2015, p-319.
12. Charak Samhita of Agnivesa, by Kashinath Shastri,part 1, 2016, chaukhamba, Varanasi p-775.
13. Pandit Kashinath Pandey and Gorakhnath Chaturvedi; Charak Samhita Kalpa Sthana-1chp, Savimarsha Vidyotini-Hindi Vyakhya;Varanasi; Ed 2011;Pub-Chaukhamba Sanskrit Sansthana.
14. Pandit Kashinath Pandey and Gorakhnath Chaturvedi;Charak Samhita Sutra Sthan-13chp, Savimarsha Vidyotini-Hindi Vyakhya; Varanasi; Ed 2011;Pub-ChaukhambaSanskritSansthana.Pg no 854.
15. Pandit Kashinath Pandey and Gorakhnath Chaturvedi;Charak Samhita Chikitsa sthan.7, Savimarsha Vidyotini-Hindi Vyakhya;Varanasi; Ed 2011;Pub-ChaukhambaSanskritSansthana.Pg no.456.
16. Pandit Kashinath Pandey and Gorakhnath Chaturvedi;Charak Samhita Sidhi Sthana-1chp, Savimarsha Vidyotini-Hindi Vyakhya;Varanasi; Ed 2011;Pub-Chaukhamba Sanskrit Sansthana .Pg no 712.
17. Ashtanga Hridayam of Vagbhatt, Edited by Dr Brahmanand Tripathi, ChikitsaSthana, Chapter-21, Verse 57-60
18. Rasendra Sara Sangraha of Sri Gopal Krishna Bhatt, Edited by G. Prabhakar RaoJwaraRogadhikar 13-10

Table-1 Schedule of Snehapana

Date	Time	Dose	Time of Hunger
06/01/2022	7 AM	35 ML	12:30PM
07/01/2022	7:10 AM	60 ML	2PM
08/01/2022	7 AM	90 ML	2:30PM
09/01/2022	6:45 AM	120 ML	2:45PM
10/01/2022	6.50 AM	150 ML	2.30 PM
11/01/2022	7.15 AM	180 ML	3.45 PM
12/01/2022	6.45 AM	210 ML	4.50 PM

Table-2 Showing Vamana Karma Proforma

Time	Name of the drug	Quantity	Veg a	Upa - vega	Output	Sign, Symptom s	Vitals	Complication if any
6:55A M	Yavagu	80 gms					Bp- 124/82mmHg Pulse- 78/min	
7:08A M	Dugdha	6 Glass		2	Dugdha		Bp- 128/ 80 mmHg Pulse- 82/min	





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7:13A M	“	2 Glass	1		Dugdha + kapha			
7:16A M	Medicine- Madhanphalapi alliChurna)= 8 gm, YastimadhuChurn a = 4 gm, Saindhava Lavana = 1 gm and Honey = Quantity sufficient						Bp- 132/80mmH g Pulse-84/min	
7:37A M						Sweda- pravarti	Bp- 126/90 mmHg Pulse-76/min	
7:41A M	Yastimadhufanta	5 Glass	2		Dugdha +kapha			
7:43A M	“	2 Glass	1	2	Kapha+ Fanta		Bp- 132/84 mmHg Pulse-82/min	
7:46 AM	“	1 Glass		1	Kapha+ Fanta			
7:50A M	“	2 Glass	1		Kapha+ Fanta		Bp- 144/86mmH g Pulse- 84/min	
7:52A M	“	1 Glass		1	Kapha+ Fanta			
7:55A M	“	2 Glass	1		Medicine		Bp- 140/80mmH g Pulse-86/min	
7:56A M	Lavanodak	3 Glass	1	1	Kapha+ Fanta		Bp- 140/80mmH g Pulse-88/min	
7:59A M	“	2 Glass	1		Fanta+ yavagu		Bp- 140/90mmH g Pulse-88/min	
8:02A M	“	2 Glass	1	1	Lavanau dak			
8:07A M	“	2 Glass		2	Lavanau dak		Bp- 136/88 mmHg	





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						Pulse-84/min
8:12A M	“	2 Glass	2	<i>Lavanaudak+pitt a</i>		Bp- 138/92 mmHg Pulse-90/min

Table – 3 Discharge Advice: (Shamanoushadhi was given from 21-01-2022 To 20-02-2022)

Sr.	Medicine	Dose and Dosage	Duration
1	<i>Arogyavardhini Vati</i>	2 TID A/F	30 days
2	<i>PanchatiktaGhritaGuggulu</i>	2 TID A/F	30 days
3	<i>GandhakRasayan</i>	2 TID A/F	30 days
4	<i>ManjishthadiKashayam</i>	40 ml BD B/F	30 days

Table- 4 Showing Shuddhi Criteria

Sr. no.	Vamana Karma criteria	Remarks
1	<i>Vegiki</i>	<i>Uttam shhudhi</i> attained (i.e. 9 <i>Vega</i> observed)
2	<i>Laingiki</i>	<i>Samyak Vamana Lakshan</i> observed
3	<i>Maniki</i>	<i>Madhyam</i> (11 litres)
4	<i>Aantiki</i>	<i>Pittanta</i> attained.

Table-5 Showing Subjective Criteria

SYMPTOMS	GRADE				
	0	1	2	3	4
<i>Aswedanam</i>	Normal	Mild sweating	Mild Sweating after exercise	No Sweating after exercise	<i>Aswedanam</i>
<i>Mahavastu</i>	No lesions	Lesions on Partial part of Hand, leg, neck, scalp, back	Lesions on most part of Hand, leg, neck, scalp,back	Lesions on whole Part of Hand, leg, neck, scalp,back	Whole body
<i>Matsyashakalopam</i> (Scaling)	No scaling	Mild scaling by rubbing or itching from some lesions	Moderate scaling by rubbing or itching from some lesions	Severe scaling by rubbing or itching from some lesions	Without itching severe scaling
<i>Kandu</i>	No itching	Occasional itching	Frequent but tolerable itching	Very severe itching	Very severe itching disturbing sleep and day to day activities
<i>Rukshata</i>	Normal skin	Slightly dry skin	Excessively dry skin	Lichenified skin	Bleeding through skin
<i>Varna</i>	Normal coloration	Slight discoloration	Reddish discoloration	Slight reddish black discoloration	Black disc discoloration
<i>Daha</i>	Absent	Occasional	Frequent <i>daha</i>	After itching started	Continues <i>daha</i>





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<i>Vedana</i>	Absent	Mild	Moderate	Severe	Very Severe
<i>Pidaka</i>	Absent	Disappears but discoloration persists	<i>Pidaka</i> in <5sq.cms. in whole of the affected area	<i>Pidaka</i> in between 5-10sq.cms. in whole affected area	Many or uncountable <i>Pidaka</i> in whole of the affected area

Table- 6 Showing Observations during Treatment

Signs & Symptoms	Before <i>Snehapana</i>	After <i>Snehapana</i>	After <i>Vamana</i>	After <i>Samsarjana Karma</i>
Auspitz sign	2	1	1	0
Candle grease sign	1	1	1	1
PASI scoring	25.8	23.2	19.6	10.6
<i>Matsyashklopan</i> (Scaling)	3	2	1	0
<i>Mandloutpati</i> (patches)	3	2	1	1
<i>Kandu</i> (Itching)	3	2	1	1
<i>Rukshata</i> (Dryness)	3	2	1	0
<i>Vaivarnya</i>	3	2	1	1



Fig 1: Before treatment

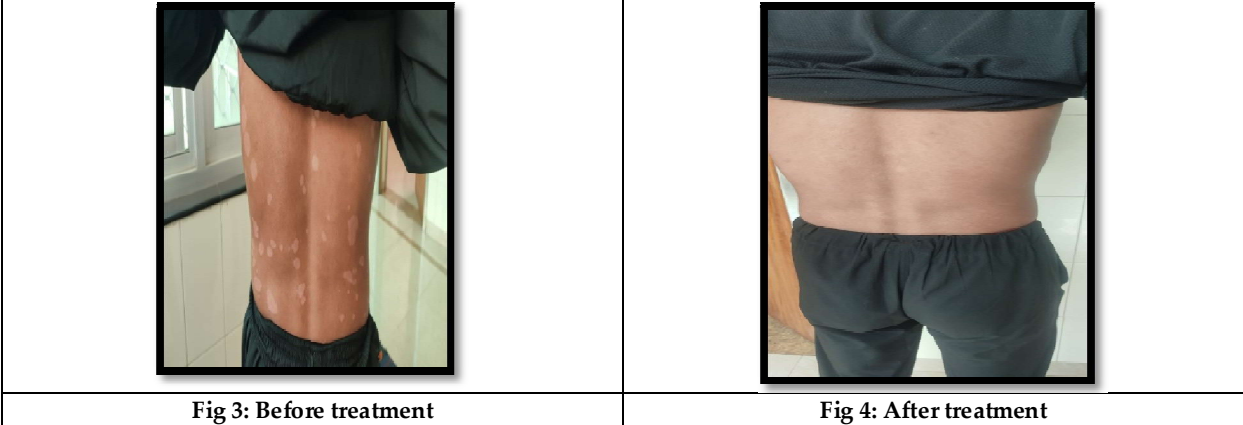


Fig 2: After treatment





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Review Article on Future Prospects of Hydropower

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ABSTRACT

With the global energy crisis, major sustainability issues such as pollution, climate change, and green house effects of CO₂ exist. Because conventional energy resources such as fossil fuels contribute significantly to the problem, using alternative energy resources is essential. Electricity (current) production is currently increasing as a product of the use of eco friendly renewable energy resources. Hydro power energy production is one of the largest, most efficient, and eco friendly renewable energy resources used to generate electricity. The potential, benefits, and limitations of hydel energy technologies are highlighted in this article. This also illustrates the future prospective for hydel energy technologies.

Keywords: hydel energy, benefits, limitations, future perspective



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INTRODUCTION

Water is a renewable energy resource and a form of non-conventional energy resources (Masoud, 2020). Alternate renewable energy resources include hydro power, geothermal, wind energy and solar energy (Ang *et al.*, 2022). Water energy is referred to as hydro power. The sustainable development of global electric power sector has been benefited greatly from small and large scale hydroelectric power. The Hydropower is more efficient than combustion technologies because it works with kinetic energy (Hafezi & Alipour, 2021). Reliability of hydropower satisfies the demand fluctuations of power it supplies to the systems. Hydropower (hydel) energy is converted into electrical energy by water flowing from a reservoirs, as well as spring and winter rainfall from mountain peaks, water supply to catchment area that are stored in reservoirs as potential energy. When water falls due to gravity, the potential energy converted into kinetic energy. Kinetic energy is used to run turbines and generate mechanical energy. Mechanical energy is converted into electrical energy by generators (Koç, 2022). Hydroelectricity is vital for the survival of domestic communities. In order to develop, build, expand, modern innovations and an increasing number of people require massive amounts of electricity (Kougias *et al.*, 2019). Hydroelectric facilities offered up to 40% of the electricity generated in the 1920s. While the amount of energy produced by these methods has steadily increased, the output of various kinds of power plants has risen at a faster rate (Enel green power, 2019). Hydroelectric power energy currently accounts for about 10% of total electrical generating capacity in the United States (Bauer, 2020). Hydropower is a important component of the national power grid because it is able to react immediately to rapidly shifting loads or system disruptions, whereas base load plants with steam systems operated by combustion or nuclear processes cannot (Eia/Doe, 2022). A further important field for hydel power research is the most use of alternative fuels to address global carbon emissions and climate change (Almeida *et al.*, 2019). This has been predicted that its application in the transport sector will grow significantly in the future because it doesn't require the transportation of fuel. The use of this renewable energy system in the energy production sector had been made possible by policies, investments, and research funding from various governmental and non-governmental organizations (Charles Rajesh Kumar & Majid, 2020). The hydel energy technologies are discussed in this paper in terms of their potential, prospects, limitations, and future directions. This will guide to a better understanding of hydel energy and its potential to meet projected energy needs.

Potential of hydel energy technologies

Hydroelectricity is produced by flowing water and utilizing water. Given that the sun drives the hydrological cycle, which provides precipitation to the earth, it can be considered a form of solar energy. Precipitation is how atmospheric water gets to the earth's surface. The Figure 1 (Edwards *et al.*, 2015) shows hydrologic cycle. The greater part of this water flows into the soil or becomes surface runoff, with some evaporating. Water from precipitation and snowmelt eventually makes its way to ponds, lakes, reservoirs, or oceans, where evaporation occurs constantly. Energy cannot be created or destroyed in nature, but its form can. No new energy is produced when electricity is produced (Hafezi & Alipour, 2021). Actually, energy is changed from one form to another. Water flow needs to be moving in order to generate electricity. This energy is kinetic (moving) energy. The energy converts into mechanical energy, when water is used to rotate a turbine's blades. The generator's rotor, which is turned by the turbine, transforms the mechanical energy into electricity. We refer it as hydroelectric power, or simply hydropower, since water is the initial source of energy. Hydropower is produced in places known as hydroelectric power plants. While some power plants are situated on waterways, rivers, and channels, dams are required for a dependable water supply. Dams hold water in reserve for later release to be used for power production, domestic and industrial use, and irrigation. The reservoir functions similarly to a battery, storing water that can be released when electricity is needed. Water flows from a head and height that the dam creates. Water is transported from the reservoir to the turbine by a penstock. The turbine blades are propelled by the swiftly moving water in a manner akin to a pinwheel in the wind. The rotor, of generator is turned by the force of water on turbine blades. Electricity is created when the rotor's wire coils pass the generator's stationary coil. Figure 2 (Kaunda *et al.*, 2012) depicts the essential parts of a hydropower facility.



**Malathi et al.,****Benefits of hydel energy technologies**

Power in engineering is the rate of work being done in relation to time. The work could be mechanical, and electrical in nature. Hydropower is used to generate electricity, and run machinery. Small-scale hydropower projects that used to generate energy to small-scale mechanical tools and machines for pressing, milling, grinding, and sewing applications are the main examples of the mechanical application. In some cases, the small-scale hydropower turbine's output shaft is extended in both directions to create space for both the production of mechanical power and electricity. Electricity is typically produced at large hydroelectric facilities. The turbine output shaft is connected to the generator to produce electricity. The electromagnetic rotor, also known as the conductor, is the main component of the generator. It is housed inside a cylinder called the stator, which also contains a winding of electric wires. The rotor in the stator rotates while operating and produces electricity using the electromagnetic induction principle. A transmission system that includes elements like a transformer backyard, and transmission lines transports the generated electricity to load points. Hydroelectricity production technology is mentioned as one of the lowest when speaking of power production expenses for an organized and - operated hydroelectricity project, possibly because the fuel can be obtained without direct costs associated with non renewable fuel purchase. For large-scale projects, the leveled cost of producing electricity ranges from 0.02 to 0.19 US dollars per kWh(Martin Kaltschmitt, 2021). One of the possible explanations for why hydel energy is recommended as base load for the majority of power utilities is the relatively inexpensive nature for power generation.

Limitations of hydel energy technologies

The main issue with hydropower construction is the impact on society and the environment of such projects, particularly large-scale ones. Separate studies must be conducted to properly identify and describe the impacts prior to the actual construction and installation of the hydropower project and plant. This is done throughout the social and ecological impact evaluation phase and can demand an enormous quantity of work time and resources depending on the features of the location and the project's size. The environment consequence evaluation investigation must additionally suggest ways to reduce the adverse effects. Projects may be cancelled in few extreme cases if the costs and impact reduction measures are exorbitant.

Future prospects of hydel technology

The hydro power does not emit contaminants into the environment. However, it can still have a negative impact on the environment. Significant efforts have been made in the past ten years at both Federal facilities and non-Federal facilities licensed by the Federal Energy Regulatory Commission to reduce environmental effects associated with hydropower operations, such as providing safe fish passage and improved water quality. Additional opportunities for environmental improvement have been made possible by dam security initiatives and the use of newly developed computer technologies to optimize operations. However, the best way to keep hydropower economically viable in the face of rising demands to protect fish and other environmental resources remains a mystery. Rehab is committed to studies and projects to improve the efficiency of operation and ecological sustainability of hydropower facilities. Reclamation is still working to improve the dependability and productivity of the hydropower industry. Today's engineers strive to maximize both new and existing facilities in order to increase output and efficiency.

CONCLUSIONS

One of the most effective methods of producing electricity is hydropower. As a result, the technology is reliable and grow up. A power consumption can use a hydropower storage system to store energy and use other energy sources, which include wind, with variable potential to meet a nearly constant load. The hydropower project's relatively high costs and associated risks are some of its disadvantages. Small-scale hydropower is financially compatible with independent private investments as electricity entrepreneurs. The financial constraints in many developing countries for large-scale hydel projects, smaller-scale hydropower projects could be one of the best



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solutions. Furthermore, small-scale projects can be used as a stand-alone energy system for rural energy supply. As a result, hydropower can make a significant importance to improved national energy uses and security, the reduction of harmful emissions and climate change gases, the creation of new economic opportunities, and the eventual achievement of sustainable development.

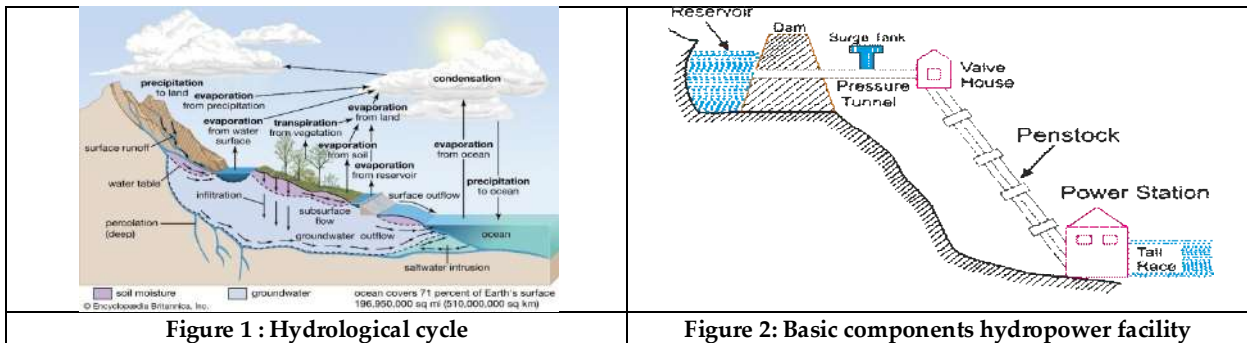
REFERENCES

1. Almeida, R. M., Shi, Q., Gomes-Selman, J. M., Wu, X., Xue, Y., Angarita, H., Barros, N., Forsberg, B. R., García-Villacorta, R., Hamilton, S. K., Melack, J. M., Montoya, M., Perez, G., Sethi, S. A., Gomes, C. P., & Flecker, A. S. (2019). Reducing greenhouse gas emissions of Amazon hydropower with strategic dam planning. *Nature Communications*, 10(1). <https://doi.org/10.1038/s41467-019-12179-5>
2. Ang, T. Z., Salem, M., Kamarol, M., Das, H. S., Nazari, M. A., & Prabakaran, N. (2022). A comprehensive study of renewable energy sources: Classifications, challenges and suggestions. *Energy Strategy Reviews*, 43. <https://doi.org/10.1016/j.esr.2022.100939>
3. Bauer, C. J. (2020). The long view of the water/energy nexus: Hydropower's first century in the U.S.A. *Natural Resources Journal*, 60(2), 173–206.
4. Charles Rajesh Kumar, J., & Majid, M. A. (2020). Renewable energy for sustainable development in India: Current status, future prospects, challenges, employment, and investment opportunities. *Energy, Sustainability and Society*, 10(1). <https://doi.org/10.1186/s13705-019-0232-1>
5. Edwards, P. J., Williard, K. W. J., & Schoonover, J. E. (2015). Fundamentals of Watershed Hydrology. *Journal of Contemporary Water Research & Education*, 154(1), 3–20. <https://doi.org/10.1111/j.1936-704x.2015.03185.x>
6. EIA/DOE. (2022). Hydropower's Contributions to Grid Resilience. *PACIFIC NORTHWEST NATIONAL LABORATORY*, 14. <https://www.energy.gov/sites/default/files/2022-08/wpto-hydrowires-day4-contributions-to-grid-resilience.pdf>
7. Enel green power. (2019). How much hydroelectric energy is produced in Italy and where. *Enel Green Power*. <https://www.enelgreenpower.com/learning-hub/renewable-energies/hydroelectric-energy/italy>
8. Hafezi, R., & Alipour, M. (2021). Renewable Energy Sources: Traditional and Modern-Age Technologies. *Affordable and Clean Energy*, 1085–1099. https://doi.org/10.1007/978-3-319-95864-4_18
9. Kaunda, C. S., Kimambo, C. Z., & Nielsen, T. K. (2012). Hydropower in the Context of Sustainable Energy Supply: A Review of Technologies and Challenges. *ISRN Renewable Energy*, 2012, 1–15. <https://doi.org/10.5402/2012/730631>
10. Koç, C. (2022). A study on solutions and problems of hydroelectric power plants in the operation. *Sustainable Water Resources Management*, 8(3). <https://doi.org/10.1007/s40899-022-00677-2>
11. Kougiaris, I., Aggidis, G., Avellan, F., Deniz, S., Lundin, U., Moro, A., Muntean, S., Novara, D., Pérez-Díaz, J. I., Quaranta, E., Schild, P., & Theodossiou, N. (2019). Analysis of emerging technologies in the hydropower sector. *Renewable and Sustainable Energy Reviews*, 113. <https://doi.org/10.1016/j.rser.2019.109257>
12. Martin Kaltschmitt, W. S. & A. W. (2021). - Hydroelectric Power Generation. *The Electric Power Engineering Handbook - Five Volume Set*, 1344–1355. <https://doi.org/10.1201/9781315222363-69>
13. Masoud, A. A. (2020). Renewable energy and water sustainability: lessons learnt from TUISR19. *Environmental Science and Pollution Research*, 27(26), 32153–32156. <https://doi.org/10.1007/s11356-020-08504-x>





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The Concept of Psychomachy and Holy Grail in Brown's *The Da Vinci Code*

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ABSTRACT

The author finds that the structure of the story is clearly marked with male characters being more important than female characters by interpreting the embedded storyline. The Da Vinci Code, to show that the female characters in the story are controlled by male narrators and are repressed so that they don't speak and are pushed to the edges of the story. This paper looks at the novel's voice and story structure from a feminist point of view on three levels: "story," "narrative discourse," and "narrating." The feminist reading of the book is not meant to play down its literary value in favor of its political value; rather, it is meant to help future research into this book. Dan Brown's complex fiction begins by questioning the usual understanding of Leonardo's art, then builds on that by questioning the system of symbols in the religious and the concept of psychomachy.

Keywords: Narrative aspects, Feminism, Holy Grail, Symbols, Psychomachy

INTRODUCTION

Dan Brown's *The Da Vinci Code* novel handles the best narrative aspects and how the author handles the two controversial concepts in this work. He also included some of famous codes, symbols and some of the secret associations. However, he has spoken about many facts and the religion he makes the readers to read the novel keenly through his style of narration. The author of this novel Dan Brown is an American author born on 22nd June 1964 in New Hampshire, U.S. He wrote his first work named, *187 Men to Avoid* ; it was published in 1995. *Digital*





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Fortress (1998), Angels and Demons (2000), The Lost Symbol (2009), Inferno (2013) and Origin (2017) these are his other works. Langdon Robert The Dan Brown series' fictional protagonist in this book studies Religious Symbolology at Harvard University. The beginning of *The Da Vinci Code* takes place in Paris, where Robert Langdon is to meet with Jacques Sauniere, the director of the Louvre Museum. Robert Langdon speaks on the gods and goddesses etched in the stones of Chartres Cathedral at the American University of Paris. Jacques Sauniere's body had codes and symbols, including the Fibonacci number sequence and a pentagram, on it when it was discovered in the midst of the night.

Sophia Neveu is a pretty police cryptographer who helps Langdon. Sophie's grandfather is Jacques Suniere. A police officer named Bezu Fache starts to chase Langdon, but Langdon gets away after being told what the captain really wants. Sophie has something that makes it easier for her and Langdon to look into an idea that many people consider to be heretical: Christ and Mary Magdalene got married and had kids together. That secret has been kept by a group of people called The Priory of Sion since the 1100s. Silas, a cruel member of Opus Dei, is also after Langdon and Sophie.

He does this so they can't find out the real story about Jesus and Mary Magdalene, where the Holy Grail is kept, or what it means. Langdon will get help from Sir Leigh Teabing, a keen British researcher, who will show them several secret messages in "The Last Supper" by Da Vinci. Another important stop for them will be the Church Temple, where a group of Templar Knights is thought to be buried, and Sir Isaac Newton's tomb at Westminster Abbey, which has some of the most important hints to the Holy Grail puzzle. A few people really enjoy this book. Henk van Klaveren wrote the very first review. He said he liked reading the book even though it wasn't written correctly. Read the book and think more deeply about what religion means to you. But don't take it as a true account of religious events. That's not what Roddy Fraser thought. He liked reading the book because it had stories based on real things that happened or ideas that people had. Nicole Gaskin added a different point of view. She liked the book a lot because it was about the Bible and was written by a great painter. But Chris Knight didn't agree. He said that Holy Blood, Holy Grail and The Da Vinci Code are perfect copies of each other. He doesn't know how it got published without him being accused of plagiarism a hundred times. It's not true at all. People of all faiths who have read them say that most of them are lies.

Narrative Aspects

he personalities and how they are shown in *The Da Vinci Code* are the first thing to think about. Robert Langdon is one of the two main characters in this story. He teaches symbols as part of his job at Harvard University. In the middle of his vacation in France, he gets caught up in a murder riddle. Sophia Neveu is the name of the second important character. She works for the Unit of Cryptology in the city of Paris. Being the granddaughter of her grandfather, she is Grand Master of the Priory of Sion. As she sets out on her trip, she hopes to find both the Holy Grail and the truth about her family.

Bezu Fache is the captain of the police department and a hard driver. It is clear that he is well-informed, always thinks ahead, and is conscious of the impact that his actions have on political affairs. Silas serves as an albino Opus Dei monk who commits murder because he is instructed to do so by The Teacher, an unidentified individual who is in charge of the investigation into the Priory's secrets. It is Silas's belief that all he acts on is for the glory of God. An Englishman named Leigh Teabing is a wealthy and peculiar individual who is obsessed with discovering the Holy Grail and has a negative opinion on the majority of French goods. It is possible for the *Da Vinci Code* to solve the crypto riddle in a very short amount of time since it resets the time to the current day. This book takes place in a variety of locations, including the "Louvre Museum, Saint Sulpice Church, Castel Gandolfo, Bois de Boulogne, and the Depository Bank of Zurich in Paris, France; the Chateau Villette in Versailles, France; the Temple Church and Westminster Abbey in London, England; and Rosslyn Chapel in Edinburgh, Scotland" (Brown 122). All of these locations are located in France. The narrative of this book is the third factor to consider. Because it is a thriller, a significant portion of the story is told through flashbacks, which might make it difficult to follow along. This synopsis will lay out the most important events in the story in the sequence in which they took place. Five months





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before to the beginning of the book, Bishop Aringarosa receives a call from the Vatican in which he is informed that the Pope has decided to no longer consider the Catholic Church to be associated with Opus Dei. The decision has been made by the Church to provide twenty million euros to Opus Dei. The church had previously obtained these sums through a loan from Opus Dei as well. In order to provide assistance to the Catholic church, Opus Dei is a covert organisation. "Doing God's Work" is the literal meaning of this phrase. "Opus Dei, which literally translates to "the Work of God," is formally regarded as the only personal prelature in the Catholic Church. This means that Bishop Javier, who is currently serving as the leader of the organisation in Rome, is the only person who holds this position" (Allen 2). Aringarosa receives a phone call from Lee Teabing a few weeks later. His attire is that of a Frenchman of religious fervour, and he refers to himself as "the teacher." During their conversation, Teabing reveals to Aringarosa that he is aware of the location of the Holy Grail. In the interim, Teabing has placed bugging devices in the residences and places of business of prominent Parisians whom he believes to be in top positions within the Priory of Sion. In the event that Teabing is in possession of sufficient knowledge, he instructs the albino monk Silas to eliminate the Grand Master and his attendants. Earlier than anything else, Silas needs to inquire about the whereabouts of the keystone. Every single one of the guys gives him the incorrect response when he kills them.

At the same time, Robert Langdon, a professor at Harvard, is in Paris giving a talk about his study. Lieutenant Collet wakes him up in the middle of the night to tell him that the Paris police need his help to figure out who killed Jacques Saunière. "Langdon weighed his words carefully. 'I was just thinking that Saunière shared a lot of spiritual ideologies with Da Vinci, including a concern over the Church's elimination of the sacred feminine from modern religion. Maybe, by imitating a famous Da Vinci drawing, Saunière was simply echoing some of their shared frustrations with the modern Church's demonization of the goddess.'" (Brown 73). Saunière left many of the clues for finding out the keystone. Brown uses a writing style that fits with the mystery and exciting tone of the book.

In spite of the fact that the chapters are brief and packed with action, they continue to hop from one story to another, none of which will be resolved until the very end. Brown frequently provides readers with just enough information to maintain their interest without divulging the entirety of the plot. For the fifth, the primary plot of this book is as follows: Robert Langdon and Sophie Neveu attempt to decipher the meaning of the message that Jacques Saunière sent and discover the secret that the Priory of Sion is keeping. The moments in this book that are considered to be the most significant are when Leigh Teabing confesses to killing the monks at the Priory of Sion and when Langdon and Sophie discover the identity of the person who murdered Jacques Saunière. One final issue arises when the purposes of religion and reason are in conflict with one another. When it comes to the concept that belief in God is based on a lack of knowledge of the truth, Dan Brown is not in agreement. A significant number of the objections are founded on assumptions and purportedly falsehoods concerning significant aspects of Christianity and the history of the Roman Catholic Church that are contained inside the book. A glimpse of the background of Dan Brown's novel *The Da Vinci Code* can be seen in the image above. The next exciting step is to do an analysis of the book. In the problem statement, there are additional specifics concerning the manner in which the researcher intends to investigate the relationship between faith and reason in *The Da Vinci Code*.

The Grail of the Holy

In Latin gradale means "gradually, in stages," which is where the word "grail" comes from. It usually refers to a chalice, dish, cup, or bowl, but it can also be thought of as a stone or something spiritual. The literary meaning of the "Holy Grail" is Sangreal. Originating in French, the term Sangraal later became Sangreal before splitting into two terms, San Greal." Sangreal is also known as Royal Blood. This is because the word has gone through many transitions and evolutions that support its meaning. The Holy Grail is a cup that holds wine. The wine represents the Holy Blood of Jesus Christ, which reminds people of how he died for them. Luke 22:20 says that Jesus said, "This cup is the new covenant in my blood, which is poured out of you." Joseph of Arimathea, Arimathea was a town in Judea in the past. The four canonical gospels in the Bible say that he was one of Jesus' disciples, but he kept this from Pilate and the rest of Jewish society because he was afraid of the Jewish leaders. He was a wealthy Jewish man who asked Pilate to bury Jesus' body after the crucifixion.: "the Grail becomes the dish in which Joseph of Arimathea gathers the blood that flows from Christ's wounds after the body is taken down from the Cross" (Barber 97). This is why it is





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called the Holy Grail. People also think of it as a way to live forever, and those who "drink" of it can spend all eternity with Jesus Christ in heaven. Religion and history are at odds with each other in the story of the Holy Grail. "The Holy Grail, she had thought, was the cup that Jesus drank from at the Last Supper and with which Joseph of Arimathea later caught His blood at the crucifixion. 'The Holy Grail is the Cup of Christ', (Brown 162)". In the world of writing, it is called an object that holds a mystery. Many people have claimed to have the holy grail and to know where it is over the ages, but no concrete evidence has ever been discovered. And throughout history, a great number of people including Knights (Night Templars- they are the Knights who are made for protecting the Christian pilgrimage on the roadside) "the Knights were in the Holy Land during the Second Crusade and told King Baldwin II that they were there to protect Christian pilgrims on the roadways" (Brown 159). This thing has a story that has to do with King Arthur and his Knights. It is thought that the person who has the Holy Grail has the favour of God, and King Arthur wanted that to happen. During the 12th and 13th centuries, when people didn't trust faith as much, this myth became a great source of hope for Europe. On the other hand, people today have different ideas and opinions about the Holy Grail. During the Romantic Era in the 1800s, Alfred Lord Tennyson and Sir Walter Scott's works rediscovered the Grail. They wrote about it in a more symbolic way, showing how it is a physical manifestation of God's grace, also known as the Eucharist, Holy Communion, or a mystical object. The search for the Grail is first featured in *Perceval, le Conte du Graal* or (*the Story of the Grail*) by Chretien de Troyes in old French. He was a French poet and known for Arthurian subjects. "The Legend of the Grail first appeared at the end of the twelfth century. It sprung as if fully armed from the head of a gifted poet called Chretien de Troyes" (Godwin 6). Many people have claimed to have the holy grail and to know where it is over the ages, but no concrete evidence has ever been discovered. And throughout history, a great number of people including Knights (Night Templars- they are the Knights who are made for protecting the Christian pilgrimage on the roadside) "the Knights were in the Holy Land during the Second Crusade and told King Baldwin II that they were there to protect Christian pilgrims on the roadways" (Brown 159), explorers, and even some of the most well-known authors in the world have looked for the Holy Grail. The Priory of Sion maintains that the story of the Grail's chalice is a masterfully crafted allegory and that it is in fact nothing at all like a cup. Put differently, the chalice in the Grail myth represents something else entirely, something far more potent. Godfrey de Bouillon is supposed to have started the Priory of Sion, a secret society in Europe, around 1099. The Priory's veneration of the sacred feminine is well-documented. "More like the pagan goddess worship cult. But more important, they are known as the guardians of an ancient secret. One that made them immeasurably powerful." (Brown 158).

The Grail had another impression that is "The Grail," Langdon said, "is symbolic of the lost goddess. When Christianity came along, the old pagan religions did not die easily. Legends of chivalric quests for the lost Grail were in fact stories of forbidden quests to find the lost sacred feminine" (Brown 322). The Langdon series of Dan Brown says that the Priory of Sion is the Worship cult of the Pagan Goddess- the Goddess of fertility and fecundity and who were all forbidden for the Israelites worship by the Yahweh God. There is a Biblical history behind the transformation of name of this secret society which was transformed by Our Lady of Sion and this was from the Old Testament of the Bible, when King David captured the mount Zion. This association is central to the secret at the heart of the Dan Brown's Novel and this secret society is said to be the protector of the bloodline of Jesus and Mary Magdelene.

CONCLUSION

He illustrates how people used to worship goddesses in the past by telling the narrative of the hunt for the Holy Grail. A variety of unusual facts, fictional stories about his characters, historical events, mythology, and religious beliefs are included in it. Brown considers himself to be a Christian, and he has stated that the issues that the characters in *The Da Vinci Code* face are significant to him on a personal level. On numerous occasions, he has stated that the *Da Vinci Code* was not intended to incite hatred towards the church but rather to initiate a discussion about the function and significance of the church. On top of that, Brown does not assert that each and every one of the actors' statements is entirely accurate. However, following the publication of Brown's book, a large number of irate





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Christians and Catholics created books in which they criticised his theories regarding a variety of topics, including the Holy Grail, Mary Magdalene's link with Jesus, and the veracity of the Gospels that are not considered canonical.

REFERENCES

1. Allen, John L., Jr, *Opus Dei: secrets and power inside the Catholic Church*, London, England: Allen Lane, 2005
2. Barber, Richard W, *The Holy Grail: Imagination and Belief*, Cambridge, MA: Harvard University Press, 2004
3. Godwin, Malcom, *The Holy Grail*, Viking Studio Books, 1994
4. Benson, Micheal, *Inside secret societies: what they don't want you to know*, New York, NY: Citadel Press, 2005
5. Cox, Simon, *Cracking the Da Vinci Code: the facts behind the fiction*, London: Michael O'Mara, 2004





Prevalence of Incidental Cone Beam Computed Tomographic Findings Among Rural Population of Western Maharashtra : A Retrospective Study

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ABSTRACT

According to Cha *et al.*, [6] incidental findings are defined as any and all discovered finding detected by CT, MRI, CBCT, or any other imaging modalities that are unrelated to the clinical indication for the imaging being performed. The presence of these incidental findings may raise concerns about the need for further diagnostic processes for specialists. According to the American Academy of Oral and Maxillofacial Radiology (AAOMR) and the European Academy of Dento-Maxillofacial Radiology (EADMFR), a clinician needs to fully examine and interpret the whole CBCT dataset. If the clinician is not an expert in interpreting the entire dataset, a referral is required for a review by oral and maxillofacial radiologists. [1,7]

Keywords: The presence of these incidental findings may raise concerns about the need for further diagnostic processes for specialists.





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INTRODUCTION

Cone beam computed tomography (CBCT) in recent years has gained popularity among dental practitioners and has become a preferred three-dimensional, diagnostic imaging modality in the maxillofacial region. Differing from traditional two-dimensional radiographic techniques, structural superimpositions, image enlargement, and distortions are absent in CBCT[1] Moreover, CBCT allows precise three-dimensional visualization of maxillofacial structures at a lower radiation dose in comparison o computed tomography (CT).[2,3] It is routinely advised for reasons including implant planning, orthodontic treatment planning, trauma, pulp and periapical pathologies, temporomandibular joint (TMJ) evaluation, and evaluation of cysts and tumors.[4] CBCT incorporates a wider anatomical region further than the dentoalveolar complex, and this frequently leads to the detection of findings that are beyond periphery of the primary region of the scans. These are named “incidental findings” and defined as “any concealed finding, benign or pathological, that is distinct to the clinical indication by which the imaging modality was originally approved[5] According to Cha *et al.*,[6] incidental findings are defined as any and all discovered finding detected by CT, MRI, CBCT, or any other imaging modalities that are unrelated to the clinical indication for the imaging being performed. The presence of these incidental findings may raise concerns about the need for further diagnostic processes for specialists. According to the American Academy of Oral and Maxillofacial Radiology (AAOMR) and the the European Academy of Dento-Maxillo facial Radiology (EADMFR), a clinician needs to fully examine and interpret the whole CBCT dataset. If the clinician is not an expert in interpreting the entire dataset, a referral is required for a review by oral and maxillofacial radiologists.[1,7] Findings such as anatomical variations are usually asymptomatic and can be left untreated. However, some others may require intervention. Detection of these findings will significantly improve patient care and be life-saving for a few of them.[5] This study aims to determine the prevalence of such incidental findings further emphasizing the role of oral and maxillofacial radiologists in interpreting such scans.

MATERIAL AND METHODS

The present cross-sectional retrospective study comprises 206 consecutive records of CBCT scans undertaken at the department of Oral Medicine and Radiology. Approval from the Institutional Ethical Committee was taken before the start of the study. CBCT data of patients who were referred for diagnosis and treatment planning such as implant planning, maxillofacial surgeries including trauma, cyst & tumors, impacted teeth, orthodontic evaluation, endodontic evaluation were included for the analysis. Age, gender, and indication for radiographic examination were recorded. Small FOV scans and scans having poor diagnostic quality probably due to positioning errors or motion artifacts were excluded. Radiographic findings that are directly related to the primary indication for CBCT scans are excluded. Images of low-resolution quality or the presence of metallic/motion artifacts in the scan were also excluded from the study sample. Segmented CBCT scans are excluded from the study because only the area of interest is included in these scans without any incidental findings All CBCT scans included in the study were obtained using Dentium Rainbow CT unit, having standard resolution mode made of voxel size of 0.3 mm using Rainbow CT Scanner [made in Korea] using 70-110 kVp, 7-10 mA, 10-20 secs, and FOV of 10 x 16 cm. An experienced oral radiologist analyzed the CBCT scans in an ambient environment and ideal conditions and any abnormalities seen were noted. Coronal & sagittal sections were prepared with 1 mm thickness at an interval of 0.5 mm. A software program, Dentium 3D imaging software (rainbow viewer) was used to reconstruct the images and perform the measurements. The data obtained were tabulated and subjected to statistical analysis using descriptive statistics.

RESULTS

Table1 shows the total frequency of males (51.9) and females (48.1) CBCT scans with a total of 206 Scans. The mean age of the scanning reports was found to be 36.17±16.06 with minimum age of 11 years and maximum of 73 years.





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Graph 1 explains scanning advices for the following reasons in both genders. Endoscan was the most common reason being 56 endo scans in males and 45 in females. Second most common reason for the scan being implant with 42 males and 39 females. Female CBCT scans out numbered the male scans for reason of impacted teeth. But it was found that the number of scans for ortho patient was equal for both males (2) and females (2) and only one female scan for follow up fracture case. Table 2 shows the frequency of incidental findings from CBCT scans of both genders. In the category of incidental findings, it was found that a total of 3 scans (1.45%) of Maxillary Sinus Complete Opacification were discovered and 4 scans (1.94%) of Maxillary Sinus Partial Opacification were found. Mucosal Retention Cyst accounted for 11 (5.33%) of scans with 8 males and 3 females. There was (1.5%) incidence of Discontinuation of Maxillary Sinus with 2 females and 1 male. Osteosclerosis, was discovered in 3 scans (3.5%) with 1 male and 1 female. Tori, Nasal Conchae Hyperplasia and Cystic Lesion was completely absent in our findings. Bifid mandibular Canal, Elongated Styloid Process, Deviated Nasal Septum and Mucosal polyp was present in only 1 male scan (0.5%). There was (2.4%) incidence of Retromolar Canal accounting for 3 male and 2 females. Impacted teeth was discovered in 11 (5.35%) of cases incidentally with 5 males and 6 females. Foreign body was discovered in both males (1) and females (1) with equal predilection. Benign Tumour / Cyst was found with equal incidence in both genders with 14 (6.8%). Osteoarthritis of TMJ was present in 2 (1%) of scans. Mucosal Polyp was detected in 9 (4.36%) reports with 6 males and 3 females. Overall, there was 102 scans (49.5%) which did not show any significant findings with 49 male scans and 53 female scans.

DISCUSSIONS

A great amount of dimensional accuracy along with sub-millimeter resolution, multiplanar, and spatial visualization is offered by CBCT. Nonetheless, an interpretation of CBCT images requires acquaintance with the anatomy of the area of interest, an understanding of the spatial relationships of the image volume, a sound knowledge of the possible diseases, anatomical variations, and abnormalities that affect the maxillofacial area and, finally, competence when formulating a differential diagnosis [8,9]. Therefore, the aim of the present study was to retrospectively evaluate the prevalence, type, and location of incidental findings on CBCT scans performed for diagnostic purposes in patients attending Pravara Institute of Medical Sciences, Rural Dental College, Loni. In this study, 206 CBCT scans were evaluated retrospectively for incidental findings. The primary indication for a CBCT scan in our study was for Endoscan followed by implant which is in contrast to a study done by Khojastepour et al. [10] and Price et al. [11] where implant planning was the main reason for a CBCT request followed by surgery. The prevalence of incidental findings in our study was 51% which is similar to a study done by Pazera et al. [12] [46.8%]; Hahnel et al. [13] [63%], Kumar et al. [58%] [14], Ritter et al. [15] [56.3%]; lower than the studies Chaet et al. [6] [24.5%] and Lim and Spanger [16] [27.5%]. In contrast to a study by Bolger et al. [17] [82.2%], Rai, et al. [1] [100%], Kamble, et al. [5] E.H. Zain-Alabdeen et al. The overall prevalence of incidental abnormal findings was found to be 51% with the prevalence of Maxillary sinus Complete Opacification (1.4%), Maxillary sinus partial Opacification (1.94%), Mucosal thickening being (16.5%), Mucous retention cyst (5.33%), Discontinuation of Maxillary Sinus (1.5%), Osteosclerosis (1.5%), Bifid mandibular canal (0.5%), Retromolar canal (2.4%), Impacted teeth (5.35%), Foreign body (1.0). In the present study, the most prevalent finding was mucosal thickening [16.5%] which is in accordance with the studies conducted by Lim and Spanger [6] [16.8%], Pazera et al. [12] [23.7%]; Raghav et al. [19] [35.1%] and Carmeli et al. [20] [36.1%]. Dobelet et al. [21], Kihara et al. [22] and Shiki et al. [23] also found mucosal thickening as the most prevalent finding in their studies but the prevalence was significantly higher [48.5%, 43% and 49% respectively] than the present study. Contrary to the findings of previous mentioned studies, Vallo et al. [22] [12%] found lower prevalence of mucosal thickening in their studies. Highest prevalence of mucosal thickening was found in the study conducted by Rai, et al. [1] [83.4%]. Irritation can cause the development of mucosal thickenings in the maxillary sinus. These irritations can result from odontogenic factors, trauma to the maxillofacial region and infections of the nasal conchae and hypersensitivity to non-infectious particles. When planning treatment for maxillary posterior implants with sinus graft, it is critical to consider the potential of pathoses in the sinus region which can have an impact on the prognosis of the implant [24].





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In our study, incidental findings occurring in the TMJ region was 1%. Previous studies reported it to be in the range of 2.6% to 26.5%.[7,25] Patients showing any incidental pathological finding in TMJ region could be symptom free clinically and may not be experiencing any TMJ dysfunction. These patients have to be educated and monitored by the clinician as they are showing incidental findings, which can act as a predisposing factor for other pathologies. Patients presenting with symptoms such as pain and limitation of mandibular function require a complete work-up and comprehensive TMJ analysis.[11] In the present study Retromolar Canal was evident in 5 cases (2.4%). In the literature studies done by the following authors Karthikeya patil et al (72.5%), Nikkerdar N et al (22%), Badry et al.(11.2%), Qureshi AA et al (18%) suggested..al In the present study another important finding was Bifid Mandibular Canal in one case (0.5%) there are various studies done on the incidence of mandibular canal by various authors Kang GH (10.2%), Soman et al (28.7%), Freitas GB et al (30.0%) suggested.

CONCLUSIONS

As oral healthcare professional, these medical conditions are out of our domain and we are not expected to treat them. Careful identification and interpretation of CBCT scans irrespective pathologies involving the maxillofacial region is our moral responsibility These result can help us in preclude postoperative complications even after dental surgeries. In conclusion, oral radiologists and dentists should be attentive to these incidental findings and comprehensively evaluate the complete image to avoid over or underestimation of the underlying diseases to provide complete health care for patients.

REFERENCES

1. Rai S, Misra D, Prabhat M, Khatri M, Mallick P, Dhawan A. Unintended and unexpected incidental findings on cone beam computed tomography: A retrospective study of 1500 scans. *Journal of Indian Academy of Oral Medicine and Radiology*. 2018 Jul 1;30(3):223-9.
2. Oberoi S, Gill P, Chigurupati R, Hoffman WY, Hatcher DC, Vargervik K. Three-dimensional assessment of the eruption path of the canine in individuals with bone-grafted alveolar clefts using cone beam computed tomography. *The Cleft palate-craniofacial journal*. 2010 Sep;47(5):507-12.
3. Oberoi S, Knueppel S. Three-dimensional assessment of impacted canines and root resorption using cone beam computed tomography. *Oral surgery, oral medicine, oral pathology and oral radiology*. 2012 Feb 1;113(2):260-7.
4. Allareddy V, Vincent SD, Hellstein JW, Qian F, Smoker WR, Ruprecht A. Incidental findings on cone beam computed tomography images. *International journal of dentistry*. 2012;2012.
5. Kamble LS, Byakodi RS, Kshar AB, Paranjpe AG, Awale SS, Shete MD. Prevalence of Incidental Findings Based on Anatomical Location and their Clinical Significance on Cone Beam Computed Tomography Scans—An Observational Study. *Journal of Indian Academy of Oral Medicine and Radiology*. 2023 Apr 1;35(2):250-4.
6. Cha JY, Mah J, Sinclair P. Incidental findings in the maxillofacial area with 3-dimensional cone-beam imaging. *American Journal of Orthodontics and Dentofacial Orthopedics*. 2007 Jul 1;132(1):7-14.
7. Pette GA, Norkin FJ, Ganeles J, Hardigan P, Lask E, Zfaz S, Parker W. Incidental findings from a retrospective study of 318 cone beam computed tomography consultation reports. *International Journal of Oral & Maxillofacial Implants*. 2012 Jun 1;27(3).
8. Campbell PD, Zinreich SJ, Aygun N. Imaging of the paranasal sinuses and in-office CT. *Otolaryngologic Clinics of North America*. 2009 Oct 1;42(5):753-64.
9. Scarfe WC, Farman AG, Sukovic P. Clinical applications of cone-beam computed tomography in dental practice. *Journal-Canadian Dental Association*. 2006 Feb 1;72(1):75.
10. Khojastepour L, Haghani J, Mirbeigi S. Incidental dentomaxillofacial findings on cone beam computed tomography images of Iranian population. *Journal of Oral Health and Oral Epidemiology*. 2014 Apr 1;3(1):12-5.



**Anjum Ara J Farooqui et al.,**

11. Price JB, Thaw KL, Tyndall DA, Ludlow JB, Padilla RJ. Incidental findings from cone beam computed tomography of the maxillofacial region: a descriptive retrospective study. *Clinical oral implants research*. 2012 Nov;23(11):1261-8.
12. Pazera P, Bornstein MM, Pazera A, Sendi P, Katsaros C. Incidental maxillary sinus findings in orthodontic patients: a radiographic analysis using cone-beam computed tomography (CBCT). *Orthodontics & craniofacial research*. 2011 Feb;14(1):17-24.
13. Hahnel S, Ertl-Wagner B, Tasman AJ, Forsting M, Jansen O. Relative value of MR imaging as compared with CT in the diagnosis of inflammatory paranasal sinus disease. *Radiology*. 1999 Jan;210(1):171-6.
14. Kumar SM, Reddy GS, Naidu BR, Nimkar AS, Deivanayagi M, Chalapathi KV, Nayyar AS. Prevalence of pathologic findings in maxillary sinuses in asymptomatic patients using cone-beam computed tomography. *Annals of Indian Academy of Otorhinolaryngology Head and Neck Surgery*. 2019 Jan 1;3(1):31-7.
15. Ritter L, Lutz J, Neugebauer J, Scheer M, Dreiseidler T, Zinser MJ, Rothamel D, Mischkowski RA. Prevalence of pathologic findings in the maxillary sinus in cone-beam computerized tomography. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology*. 2011 May 1;111(5):634-40.
16. Lim CG, Spanger M. Incidental maxillary sinus findings in patients referred for head and neck CT angiography. *Singapore dental journal*. 2012 Dec 1;33(1):1-4.
17. Bolger WE, Parsons DS, Butzin CA. Paranasal sinus bony anatomic variations and mucosal abnormalities: CT analysis for endoscopic sinus surgery. *The Laryngoscope*. 1991 Jan;101(1):56-64.
18. Zain-Alabdeen EH, El Khateeb SM. Incidental cone beam computed tomographic findings among Taibah University patients, KSA: A retrospective study. *Journal of Taibah University Medical Sciences*. 2017 Apr 1;12(2):131-8.
19. Raghav M, Karjodkar FR, Sontakke S, Sansare K. Prevalence of incidental maxillary sinus pathologies in dental patients on cone-beam computed tomographic images. *Contemporary clinical dentistry*. 2014 Jul 1;5(3):361-5.
20. Carmeli G, Artzi Z, Kozlovsky A, Segev Y, Landsberg R. Antral computerized tomography pre-operative evaluation: relationship between mucosal thickening and maxillary sinus function. *Clinical oral implants research*. 2011 Jan;22(1):78-82.
21. Dobelev I, Kise L, Apse P, Kragis G, Bigestans A. Radiographic assessment of findings in the maxillary sinus using cone-beam computed tomography. *Stomatologija*. 2013;15(4):119-22.
22. Kihara E, Chindia M, Ocholla T, PaKihara, Eunice &Chindia, Mark &Ocholla, Tom & Parker, Mohamed. Clinical Significance of Pathological and Anatomical Findings in Cone Beam CT Scans of the Maxillary Sinus. *Open Journal of Stomatology*. 2014 April;06(4): 285-290.
23. Shiki, K., Tanaka, T., Kito, S., Wakasugi-Sato, N., Matsumoto-Takeda, S., Oda, M., Nishimura, S., & Morimoto, Y. The significance of cone beam computed tomography for the visualization of anatomical variations and lesions in the maxillary sinus for patients hoping to have dental implant-supported maxillary restorations in a private dental office in Japan. *Head & face medicine*. 2014 May;10(1):10-20
24. Nguyen PN, Kruger E, Huang T, Koong B. Incidental findings detected on cone beam computed tomography in an older population for pre-implant assessment. *Australian Dental Journal*. 2020 Dec;65(4):252-8.
25. Çağlayan F, Tozoğlu U. Incidental findings in the maxillofacial region detected by cone beam CT. *DiagnIntervRadiol*. 2012 Mar;18(2):159-63.
26. Patil K, Sanjay CJ, Devi KR, Nagabhushana D, Viveka S, Girish MS. Retromolar canal: a classic analysis with CBCT in South Indian population. *Eur J Anat*. 2022;26(6):703-8.
27. Nikkerdar N, Golshah A, Norouzi M, Falah-Kooshki S. Incidence and anatomical properties of retromolar canal in an Iranian population: a cone-beam computed tomography study. *International journal of dentistry*. 2020 Mar 9;2020.
28. Badry MS, El-Badawy FM, Hamed WM. Incidence of retromolar canal in Egyptian population using CBCT: a retrospective study. *Egyptian Journal of Radiology and Nuclear Medicine*. 2020 Dec;51:1-8.
29. Qurishi AA, Bakri MM, Mustafa A, Altowarqi SA. Incidence And Evaluation Of Retromolar Canal With CBCT In The Population Of Jazan Saudi Arabia-Our Experience With Review. *Journal of Pharmaceutical Negative Results*. 2022 Dec 31:1747-50.





Anjum Ara J Farooqui *et al.*,

30. Kang JH, Lee KS, Oh MG, Choi HY, Lee SR, Oh SH, Choi YJ, Kim GT, Choi YS, Hwang EH. The incidence and configuration of the bifid mandibular canal in Koreans by using cone-beam computed tomography. *Imaging science in dentistry*. 2014 Mar;44(1):53.
31. Soman C, Wahass T, Alahmari H, Alamri N, Albiebi A, Alhabashy M, Talha A, Alqhtani N. Prevalence and Characterization of bifid mandibular Canal Using Cone Beam Computed Tomography: A Retrospective Cross-Sectional Study in Saudi Arabia. *Clinical, Cosmetic and Investigational Dentistry*. 2022 Jan 1:297-306.
32. Freitas GB, Morais LA, Silva MB, Silva TC, Manhães Júnior LR. Incidence and classification of bifid mandibular canals using cone beam computed tomography. *Brazilian Journal of Oral Sciences*. 2015 Oct;14:294-8.

Table 1: Frequency of gender in incidental findings from CCT scans

Gender	Number	Percentage
Male	107	51.9
Female	99	48.1
Total	206	100
Age(Mean±SD)	36.17±16.06(Min11-Max73)	

Table 2: Frequency of incidental findings from CBCT scans

Category of Incidental Findings	Males No.(%)107(51.9)	Females No.(%)99(48.1)	Total No.(%)206(100)
Maxillary Sinus Complete Opacification	1	2	3(1.45%)
Maxillary Sinus Partial Opacification	3	1	4(1.94%)
Mucosal Thickening	22	12	34(16.5%)
Mucosal Retention Cyst	8	3	11(5.33%)
Discontinuation of Maxillary Sinus	1	2	3(1.5%)
Osteosclerosis	1	2	3(1.5%)
Tori	0	0	0
Bifidmandibular Canal	1	0	1(0.5%)
Retromolar Canal	3	2	5(2.4%)
Impacted Teeth	5	6	11(5.35%)
Nasal Conchae Hyperplasia	0	0	0
Cystic Lesion	0	0	0
Non-Significant	49	53	102(49.5%)
Foreign body	1	1	2(1.0%)
Elongated Styloid Process	1	0	1(0.5%)
Osteoarthritis of TMJ	2	0	2(1%)
Benign Tumour/Cyst	7	7	14(6.8%)
Deviated Nasal Septum	1	0	1(0.5%)
Mucosal Polyp	6	3	9(4.36%)





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<table border="1"> <caption>Reasons for scanning</caption> <thead> <tr> <th>Reason</th> <th>Males</th> <th>Females</th> </tr> </thead> <tbody> <tr> <td>Endoscan</td> <td>56</td> <td>45</td> </tr> <tr> <td>Impacted teeth</td> <td>3</td> <td>8</td> </tr> <tr> <td>Implant</td> <td>42</td> <td>39</td> </tr> <tr> <td>orthodontic patient</td> <td>2</td> <td>2</td> </tr> <tr> <td>Followup</td> <td>0</td> <td>1</td> </tr> <tr> <td>Not present Fr.</td> <td>4</td> <td>4</td> </tr> </tbody> </table>	Reason	Males	Females	Endoscan	56	45	Impacted teeth	3	8	Implant	42	39	orthodontic patient	2	2	Followup	0	1	Not present Fr.	4	4	
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<p>Graph 1: Reasons for scanning advice</p>	<p>Figure 1. showing Bifid Mandibular canal.</p>																					
<p>Figure 2. Showing Mucosal Thickening.</p>	<p>Figure 3. showing Mucous Retention Cyst and Mucosal Polyp.</p>																					
<p>Figure 4. showing Retromolar canal.</p>																						





Exploring Knee Osteoarthritis Diagnosis through Efficient Mixture of Machine Learning and Deep Learning Models: A Comprehensive Review

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ABSTRACT

Osteoarthritis (OA) is one of the most common joint diseases in the universal, the joints most commonly affected are the hip, knee, shoulder, the big toe, and the base of the thumb, with a collective occurrence due to aging. In knee osteoarthritis (KOA), the harm to the joints is everlasting, and the only treatment is total knee replacement (TKR). It causes joint pain and disability, reduced worth of life, and a massive burden on healthcare services for society. However, there are many problem-solving methods that are suitable for early diagnosing patients with KOA. The use of machine learning (ML) and deep learning (DL) in OA diagnosis has improved intensely in the past few years. Hence, in this review article, we fine-tune and give the comparatively best accuracy to describe the research progress in the application of ML and DL in the early diagnosis of KOA and classify the KOA from a radiograph with the Kellgren-Lawrence (KL) grading system with a comparison used to measure the severity of OA in the knee. In this paper, we compared the recent research paper on KOA detection and classification with a comparison of ML and DL models by using a radiograph. After a thorough literature survey, we have come up with a new proposed detection model, classification model, and fine-tuning KOA diagnosis model using the latest version of YOLO in deep learning (DL) technique to improve the efficiency of KOA diagnosis. Our proposed model will decrease the cost of diagnosis, get a faster diagnosis, and delay disease movement, enhancing the technique from the patient's point of view. The proposed model will determine the degree



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of KOA diseases by making multi-classification and binary classifications of the KOA severity, and this proposed work would be particularly helpful in situations where medical personnel may not be available.

Keywords: Osteoarthritis (OA), Knee Osteoarthritis (KOA), Machine Learning (ML), Deep Learning (DL), X-Ray, Kellgren-Lawrence (KL), Diagnosis, Classification, Fine-tuning, YOLO.

INTRODUCTION

Osteoarthritis (OA) is a prevalent joint syndrome, commonly affecting joints such as the hip, knee, shoulder, big toe, and the base of the thumb. The gradual breakdown of articular cartilage, leading to osteoarthritis, can occur naturally with age or as a secondary condition resulting from factors like injury, trauma, or repetitive stress. The progression of articular cartilage collapse is a gradual process. The findings in radiographic imaging vary depending on the stage of OA, with descriptions like "localized or diffuse" and gradations such as "mild, moderate, or severe" guiding treatment decisions. Also known as "Progressive Joint Disease" or "Wear and Tear arthritis," OA is the most common musculoskeletal disorder, primarily affecting weight-bearing joints such as the hip, knee, spine, feet, and fingers. [4] Various factors like age, heredity, injury, hormone disorders, repeated trauma, uric acid, or diabetes contribute to knee OA. While knee OA commonly occurs in old age due to cartilage wear, it can affect younger individuals due to joint injury or repetitive stress. The treatment of OA can be costly, posing a significant economic burden globally. [5]

Knee osteoarthritis

Knee osteoarthritis (KOA), also referred to as degenerative knee joint disease, typically results from the gradual wear and tear and progressive deterioration of articular cartilage. This condition is most prevalent among the elderly and is categorized into two types: primary and secondary. Primary osteoarthritis has no cause, while secondary osteoarthritis is a consequence of abnormal force concentration across the joint, as seen in post-traumatic cases, or abnormal articular cartilage, as observed in conditions. Symptoms vary in intensity for each individual and generally progress slowly. Common clinical indicators include gradual onset knee pain exacerbated by activity, stiffness, swelling, pain after prolonged rest, and crepitus during joint movement. Treatment for knee osteoarthritis typically commences with conservative methods and may advance to surgical options if conservative approaches prove ineffective. While medications can help slow the progression of inflammatory conditions, there are currently no established disease-modifying agents for treating knee OA. [1][2][7]

Imaging examinations for osteoarthritis conventional radiographs – Routine X-ray examinations

Irrespective of the affected joint, osteoarthritis presents distinct features on conventional radiographs (X-rays), setting it apart from other joint disorders like rheumatoid arthritis. Specifically, an X-ray of an osteoarthritic joint reveals a narrowing of the space between the bones where cartilage has eroded, as depicted in the image below. Anteroposterior (front to back) X-ray image of the knee illustrating osteoarthritis. Note the reduced spacing on the right side, indicating cartilage degeneration. When cartilage is lost, bone rubs against bone. This can root to lumps or fluid-filled cracks can form in the bone, which will also be observable in an X-ray. The body also rejoins with induration (increased bone density), in which more bone produces where the cartilage casts off to be. The joint surfaces develop misaligned and osteophytes (bone spurs) may form. There are straightforward routine X-ray views for imaging each joint:

- An anteroposterior (AP) view (front-to-back view)
- A lateral (outer side) view
- One or two oblique (45-degree) views

In order to detect early cartilage wear, Hospital for Special Surgery's (HSS) uses special X-ray views in place of or in adding to these standard views. These specific views are designed to increase the sensitivity of the conventional radiographic study. [2][14]



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There are several methods for grading OA in the knee, Kellgren-Lawrence (KL) is a common approach which has five grades from 0-4.

Grade 0: Normal knee health.

Grade 1: Minimal bone spur growth with no pain or discomfort.

Grade 2: Onset of symptoms, mild pain after walking, and increased stiffness. X-rays reveal greater bone spur growth, but cartilage remains relatively healthy.

Grade 3: Moderate OA with frequent pain, heightened stiffness after prolonged sitting, and evident cartilage damage.

Grade 4: Severe OA, characterized by a dramatically reduced joint space, almost complete cartilage loss, and decreased synovial fluid. This stage is associated with high levels of pain and discomfort during joint movement. [7][47]

COMPREHENSIVE REVIEW ON KNEE OSTEOARTHRITIS USING MACHINE LEARNING AND DEEP LEARNING MODEL

Sameh Abd El-Ghany et al. [1] proposed fine-tuning KOA diagnosis model using the DenseNet169 deep learning technique aims to improve the efficiency of KOA diagnosis by reducing cost, speeding up diagnosis, and delaying disease progression. - The model will determine the degree of KOA diseases through multi-classification and binary classifications, successfully localizing the opacities' peripheral, diffuse distribution, and vascular thickening. - Overall, the proposed model presents a potential solution to the limitations of current KOA diagnosis methods and offers significant improvements in diagnosing and understanding the severity of KOA. The study also involved splitting the OAI dataset into training, testing, and validation sets. (confidence: 90), OAI dataset - X-ray and MRI images of 4,746 participants, including 4,446 X-ray images with KL grades for both knees (confidence: 95) Deepak Saini et al. [2] proposed Computer-aided methods are valuable for early detection of knee OA, with a focus on automatic analysis and the potential for collaboration between machine learning algorithms and healthcare professionals. The study objectives are to introduce the reader to key directions of manual, semi-automatic, and automatic knee osteoarthritis (OA) severity classification from plain radiographs, describe recent developments in severity evaluation of knee OA from X-ray images, and primarily focus on automatic analysis and review articles in which machine learning, transfer learning, active learning, etc. have been employed on X-ray images to access and classify the severity of knee OA. The methodology involved conducting a search for original research articles on knee OA detection and classification using X-ray images, screening for articles published in English in the year 2019, categorizing the obtained articles based on segmentation methods, and including studies based on public datasets.

The review included a total of 103 references. OAI dataset, MOST dataset, BLSA, other datasets, 103 references M, Ganesh Kumar et al. [3] proposed the use of deep convolutional neural networks (CNN) in conjunction with the Kellgren-Lawrence (KL) grading system significantly improved the accuracy of knee osteoarthritis (OA) detection, achieving a mean accuracy of 91.03% with enhanced images, compared to the earlier accuracy of 72% with original knee X-ray images. - The implementation of a more effective loss function can enhance knee KL grading performance, indicating the potential for further improvements in the assessment of OA severity. - The study demonstrated that a proposed CNN model, when applied to enhanced images obtained using image sharpening techniques, achieved high training and testing accuracies, indicating the effectiveness of the image enhancement approach in improving classification performance. The dataset used in the study is the Osteoarthritis Initiative (OAI) dataset, a multi-center, long-term, prospective study aimed at identifying biomarkers for the onset and development of knee osteoarthritis (OA) through X-ray images of the knee. The dataset is publicly available through the OAI website (<https://oai.epi-ucsf.org/datarelease/>). The study also mentions that experiments were conducted using the Google Colab platform equipped with a graphics processing unit (GPU), indicating that the dataset was used for training and testing machine learning models. The specific algorithms introduced, studied, or used in the study include deep convolutional neural networks (CNN), linear support vector machine (SVM), deep neural networks (DNN), and Inception ResNet V2 CNN models. The paper also discusses the use of an initial distribution with a zero-mean Gaussian distribution and a standard deviation of 0.001 for generating the weights of the network, as well as the modification of the learning rate using an exponential decay factor. The authors suggest future research involving working on a real-time dataset with precise severity grading. This could involve expanding their study to include



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data from multiple time points beyond the baseline and potentially incorporating data from different sources to enhance the generalizability of their findings. Additionally, exploring the application of their image-enhanced system in a clinical setting and assessing its performance in real-time diagnosis and prognosis of knee osteoarthritis could be a valuable direction for future research. E. Siggstedt et al. [4] Knee osteoarthritis is a growing problem due to increasing risk factors such as age and obesity. - The project found that using transfer learning with DenseNet for MTF and PF, and using a MTF model as transfer learning model for the LTF model was the best performing transfer learning networks to use. - Comparisons of final models with the radiologist initial annotations showed that the MTF and LTF models give fewer misclassifications of more than one grade, if compared to the disagreements of more than one grade by the two radiologists. Performance of the models in grading knee osteoarthritis, with a specific focus on misclassifications of more than one grade for the MTF, LTF, and PF models (aiming for performance on par with human radiologists) The dataset used in the study is a doubly annotated dataset from around 5000 knee examinations, including X-ray images from different views, graded for osteoarthritis in three compartments (MTF, LTF, and PF). The dataset includes annotations by multiple radiologists and an orthopedic surgeon, according to the NH-scale. It also includes information about left or right knee, exclusion criteria, age, and gender. Future research could involve further exploration of different methods for building models, including evaluating various hyperparameters and network architectures, as well as experimenting with different data augmentation techniques to balance the dataset. They also propose investigating alternative approaches such as using fixed numbers of epochs instead of early stopping, trying different numbers of folds in cross-validation, and increasing the dataset through different data augmentations.

Additionally, they mention the potential for exploring the use of different dropout probabilities, delta values, patience value combinations, and learning rates, as well as considering the use of different ResNet networks for transfer learning. The authors also highlight the importance of ensuring fair comparisons between different methods and evaluating how these variations may impact model performance. Xuan A, Chen H, Chen T et al. [5] proposed ML has the potential to automate the grading systems used in X-ray imaging for osteoarthritis, improving diagnostic accuracy and consistency. - ML techniques such as LightGBM and XGBoost have shown high efficiency in diagnosing osteoarthritis, with promising AUCs and F1-scores. - The development of effective prediction models using ML could lead to the development of personalized therapies for osteoarthritis patients. The study objectives are to review the research progress on ML in the early diagnosis of OA, discuss the current trends and limitations of ML approaches, and propose future research priorities for ML in the field of OA. The methodology involved a comprehensive literature search using multiple databases and keyword searches, with a focus on articles related to machine learning and early diagnosis of osteoarthritis. The authors also considered all types of articles if they provided relevant data for the research questions. Hu J, Zheng C, Yu Q, Zhong L et al. [6] proposed the main findings of the paper are: The study aimed to assess observer differences in reading x-rays for osteo-arthritis. - Comparison of prevalence estimates by different observers may have little value in population studies. - It is suggested that x-rays in population studies should be read by the same observer or preferably by two observers in consultation. The primary outcome measured in the study is the extent of observer difference in grading x-rays for osteo-arthritis.

The dataset used in the study is a series of 510 x-rays from 85 persons in the age group 55-64, chosen at random from an urban population, which were graded for osteo-arthritis by two observers on four occasions to determine the extent of observer difference. The specific algorithms introduced, studied, or used in the study are the criteria for assessing osteo-arthritis based on radiological features, including the formation of osteophytes, periarticular ossicles, narrowing of joint cartilage, small pseudo cystic areas, and altered shape of bone ends. The paper does not explicitly suggest lines of future research. However, it implies that future research could focus on exploring methods to minimize observer bias and increase the reliability of radiological assessments in population studies. Vijaya Kishore V, V. Kalpana et al. [8] proposed Accuracy of deep learning models in detecting knee osteoarthritis (KOA) based on the KL grading scale The study objectives are to compare twelve transfer learning DL models for detecting the grade of KOA from a radiograph, assess existing prediction models for knee osteoarthritis (OA), create an automated KOA classification tool, and anticipate risk and encourage risk reduction. The methodology involved comparing twelve transfer learning DL models for detecting the grade of knee osteoarthritis from radiographs. The dataset was divided



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into training, testing, and validation sets, and Python was used for developing DL models. The study evaluated accuracy and loss as parameters for model performance. The specific algorithms introduced, studied, or used in the study are DenseNet169, DenseNet201, EfficientNetB7, InceptionResNetV2, InceptionV3, MobileNet, MobileNetV2, NASNet-Mobile, ResNet152V2, VGG19, and Xception. The dataset used in the study consists of 2618 X-ray images of knee osteoarthritis, which were divided into a training set, a test set, and a validation set in a ratio of 70:10:20. The images were in DICOM format and were processed by the algorithm, with each radiograph automatically cropped and resized to a maximum of 224 pixels. Python was used as the programming language for developing the DL models, and the Google Colab platform was used to compile the code on a GPU configuration, enabling faster processing of the models. The authors declare no competing financial interests or personal relationships that could have influenced the work reported in the paper. The future research could focus on developing and implementing new orthopaedic technologies based on the findings of this study, as well as further exploring the potential for constructing a computerized KOA classification tool.

Additionally, future research could aim to enhance the accuracy of current studies and trials in the field of AI-based medical picture categorization, ultimately leading to improved healthcare services. Ozkan Cigdem et al. [10] proposed AI applications have significantly increased in the last decade for the detection and management of knee osteoarthritis - The study, based on 35 papers, highlights the potential of AI in enhancing the detection and management of knee osteoarthritis - Deep learning has shown promising potential in fully-automated segmentation of knee cartilage and bone, as well as in accelerating MRI without compromising image quality or diagnostic accuracy. The main or primary outcome measured in the study is related to the use of artificial intelligence in the diagnosis of knee osteoarthritis, prediction of the need for total knee replacement (TKR), segmentation and localization of knee structures, and accelerating the image acquisition. Additionally, the main radiographic findings of knee osteoarthritis, including osteophyte formation, Joint Space Narrowing (JSN), and subchondral sclerosis, are also mentioned as important outcomes. Osteoarthritis Initiative (OAI) database, Multicentre Osteoarthritis Study (MOST), Prevention of Knee Osteoarthritis in Overweight Females (PROOF) the specific algorithms introduced, studied, or used in the study include Deep Learning (DL) with CNN approaches and Transfer learning (TL) scheme for KOA, risk evaluation models, ResNet-50, DenseNet-121, Convolutional Variational Autoencoder (CVAE) DL models for predicting KOA incidence, and DL models for fully-automated segmentation of knee cartilage and bone.

The paper also emphasizes the importance of external validation, reproducibility, and generalizability of DL models in clinics, as well as the challenges related to acquiring and annotating large datasets for training AI models and suggests solutions such as generating synthetic data, augmentation, and leveraging existing datasets through transfer learning. Future research should focus on ensuring reproducibility of approaches, validating DL models on current imaging protocols and patient cohorts, addressing challenges in dataset acquisition and annotation, and exploring self/unsupervised pre-training for improving generalization of DL models. Ahmed, S.M.; Mstafa, R.J et al. [21] proposed the main findings are related to the improved performance of the proposed models, particularly in binary classification, and their potential contribution to early classification in knee osteoarthritis. efficiency of the proposed approach in improving the classification accuracy in both multiclass and binary class-based in the OA case study. To develop a new method for the efficient diagnosis and classification of knee osteoarthritis severity based on X-ray images - To classify knee osteoarthritis in binary and multiclass categories. The methodology involves developing a new method to diagnose and classify knee osteoarthritis severity based on X-ray images using pre-trained CNN for feature extraction and fine-tuning with transfer learning. The study proposes various classification models for knee OA severity and evaluates their performance. The proposed Deep Hybrid Learning (DHL) models outperform existing methods. Osteoarthritis Initiative (OAI) dataset: The OAI dataset includes knee X-ray images and KL grades for both knees. It consists of bilateral posterior-anterior PA fixed flexion of knee X-ray images and was used to classify knee osteoarthritis severity based on X-ray images. The "Algorithms" introduced in the study are the two frameworks for classifying knee osteoarthritis severity based on X-ray images, using pre-trained convolutional neural networks (CNN) for feature extraction and fine-tuning the pre-trained CNN using transfer learning (TL) method. The authors suggest that future research could focus on further improving the classification accuracy in multiclass and binary class-based osteoarthritis (OA) studies. Additionally, they could explore methods to enhance early



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classification in the first stage of the disease to further reduce its progression and improve people's quality of life. Pongsakonpruttikul, N & Angthong, Chayanin et al. [24] proposed the main findings are that the deep learning models provided high accuracy and satisfactory precision for the detection and classification of early to severe knee osteoarthritis on anteroposterior radiographs. The proposed AI technology could help orthopedic surgeons and related specialists interpret knee radiographs for the diagnosis of knee OA and assist in classifying the disease severity for determining the appropriate treatment option. The methodology involved developing two models for distinguishing normal from osteoarthritic knees and classifying severity based on the Kellgren-Lawrence (KL) classification system. The study collected knee radiographs from the Osteoarthritis Initiative (OAI) and employed manual labeling of regions of interest, data augmentation techniques, and modified YOLO algorithms for model development. The models were tested using labeled knee X-ray images for both systems. The dataset used in the study is the "Knee Osteoarthritis Severity Grading Dataset" Version 1, which consists of 1650 knee joint radiographs collected from the Osteoarthritis Initiative public resource. The study also involved 4796 men and women ranging in age from 45 to 79 years. The original dataset was obtained from a public resource distributed by Pingjun Chen and is titled "Knee Osteoarthritis Severity Grading Dataset " Version 1, which was published on 4 Sep 2018 in Mendeley Data. Algorithm used YOLOv3, YOLOv3 tiny. Li, Wei & Xiao, Zhongli et al. [27] proposed the DL model with Multiview images and prior knowledge achieved the best classification performance among the 4 DL models, with a high micro average AUC and macro average AUC. The overall accuracy of this DL model was significantly better than that of an experienced radiologist. The DL model accurately detected and classified the K-L grading of knee OA, and the use of Multiview X-ray images and prior knowledge improved the classification efficacy.

The primary outcome measured in the study is the performance of the deep learning (DL) algorithm in detecting and classifying knee osteoarthritis (OA) based on plain radiographs, including accuracy, area under the receiver operating curve (AUC), and the effect of Multiview images and prior knowledge on diagnostic performance. The methodology involved retrospective analysis of knee X-ray images, utilization of Kellgren-Lawrence grading, establishment of DL models based on Multiview images and automatic zonal segmentation, receiver operating curve analysis, comparison with experienced radiologists, implementation of a DL framework with three training data processing steps, and statistical analyses using SPSS and R software. The dataset used in the study consists of 4,200 paired knee joint X-ray images from 1,846 patients, collected retrospectively from the Fifth Affiliated Hospital of Sun Yat-sen University between July 2017 and July 2020. The dataset includes knee radiography with both anteroposterior and lateral images. The inclusion criteria for the dataset were adults over 18 years old with closed epiphysis and both anteroposterior and lateral images available for each examination. The exclusion criteria for the dataset included specific conditions such as tumours that destroyed the bone in the knee, other inflammatory arthritis, fractures occurring in the knee area, congenital deformity of knee joint development, and insufficient quality of the X-ray images. The dataset includes a total of 1,846 patients, with each patient contributing a single knee joint as a sample. U-Net and ResNet-50 networks were introduced and studied as specific algorithms in the paper for the classification of knee osteoarthritis based on plain radiographs. The paper also utilized statistical analyses to evaluate the performance of the DL models. The future research could focus on gathering multicentre data to increase the comprehensiveness of the DL model, extending the training to include data from other providers, and incorporating more information to enhance the predictive ability of the model.

A. Rehman, A. Raza et al. [29] proposed the main findings are the development of a high-performance model for early detection of osteoarthritis in knee X-ray images and the effectiveness of the proposed CRK technique in extracting spatial features. Effectiveness of diagnosing osteoarthritis in knee X-ray images at an early stage using advanced deep learning-based Convolutional Neural Network (CNN) and several machine learning-based techniques) The study objectives are to improve the quality of life through early detection of osteoarthritis and to create a model for the effective diagnosis of osteoarthritis in knee X-ray images at an early stage. The methodology involves the use of advanced deep learning-based CNN, machine learning-based techniques, and a novel transfer learning-based feature engineering technique CRK to detect osteoarthritis from X-ray images. The spatial features extracted from the X-ray images are used to create a probabilistic feature set, which is then utilized to build the applied machine learning-based techniques. The study aims to revolutionize the prediction of osteoarthritis from X-



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ray images with high-performance scores. The dataset used knee-based x-ray images dataset publicly available on Kaggle, containing 3615 files with 2 classes: normal and osteoarthritis (confidence: 95), CRK (CNN Random Forest K-neighbors), Random Forest, k-neighbors, Convolutional Neural Network (CNN), Splitting, SVM, SGD, KN, Hyperparameter optimization, k-fold-based cross-validation Schiratti JB, Dubois R et al. [30] proposed the novel DL software known as MediAI-OA demonstrated satisfactory performance comparable to that of experienced orthopedic surgeons and radiologists for analyzing features of knee OA, KL grading, and OA diagnosis. The software introduced techniques to reduce the effect of individual knee size, quantify mJSW relative to tibial width, and obtain the JSN rate compared to normal knees. However, the F1 scores of KL grades 2 and 3 were relatively low compared to other grades, possibly due to the ambiguity of the definition of joint space narrowing.

Accuracy of KL grading, OA diagnosis accuracy, MSE for mJSW quantification, JSN rate quantification accuracy, Osteophyte detection accuracy, F1 scores for the diagnosis of no OA and OA, Average accuracy of automatic KL classification, Cohen's kappa coefficient (κ) between the AI model and ground truth To develop novel DL software known as MediAI-OA for assessing radiographic features of knee OA, including osteophyte and joint space narrowing, as well as grading of OA severity based on the KL system. To introduce this novel DL software for the first time. To evaluate the accuracy and performance of the MediAI-OA model for KL grading of knee OA. The dataset used in the study is the Osteoarthritis Initiative (OAI), which included 44,193 radiographs for training, 810 radiographs for validation, and 400 test datasets. The specific algorithms introduced, studied, or used in the study are Keras, TensorFlow, Scikit-learn, Torch, Torch vision, NumPy, OpenCV for software development. Deep learning models such as HRNet, RetinaNet, and NASNet were used for tasks including detection of knee joint regions, segmentation and quantitative analysis of joint space width area, determination of osteophyte presence, automatic classification of KL grade, and integration and visualization of OA features. NASNet was specifically used for automatic classification of KL grade and detection of osteophytes. The average accuracy of the automatic KL classification of MediAI-OA was reported to be 0.83, with near-perfect accuracy (0.92) when classifying KL Grade < 2 and ≥ 2 . The paper suggests several potential areas for future research, including discriminating the severity of osteophytes, evaluating subchondral sclerosis or bony abnormalities, expanding the model's capability to determine OA of the patellofemoral joint, and further refining the model to integrate the results of the three OA features and perform final KL grading.

COMPARATIVE ANALYSIS

In this, a comparative study is presented according to the KOA diagnosis, classification and fine-tuning models by utilizing different ML and DL methods which are briefly studied in below table 1. From the above table 1, the article [30-39] is studied and it is concluded that the article [1] yields better detection results for KOA detection and classification derived from the X-Ray data using various ML and DL models.

CONCLUSIONS

Knee osteoarthritis (KOA) is an important cause of physical idleness and incapacity. Initial detection and treatment of osteoarthritis (OA) collapse can decrease its progression. Deep learning methods, in conjunction with the Kellgren-Lawrence (KL) grading system, are hand-me-down to assess the severity of OA in the knee. A recent study explored knee osteoarthritis using machine learning, and the deep learning results are at different accuracy levels. In this, we learned the phases of diagnosing the KOA from x-ray images, feature extraction using deep learning, and the overall performance of the model. Image sharpening, a type of image filtering, was required to improve image clarity due to noise in knee X-ray images in anteroposterior (AP) view. The assessment used baseline X-ray images from the Osteoarthritis Initiative (OAI). On enhanced images learned by applying the image sharpening procedure, a single component of machine learning and deep learning. However, there are certain drawbacks to take into account, even though the suggested strategy helps to improve disease prediction. In the future, we intend to work on the anteroposterior (AP) view from the x-ray image dataset with precise severity grading and fine-tuning with the latest and best model.





REFERENCES

1. Sameh Abd El-Ghany, Mohammed Elmogy, A. A. Abd El-Aziz, A fully automatic fine-tuned deep learning model for knee osteoarthritis detection and progression analysis, Egyptian Informatics Journal, Volume 24, Issue 2, 2023, Pages 229-240, ISSN 1110-8665, <https://doi.org/10.1016/j.eij.2023.03.005>.
2. Deepak Saini, Trilok Chand, Devendra K. Chouhan, Mahesh Prakash, A comparative analysis of automatic classification and grading methods for knee osteoarthritis focussing on X-ray images, Biocybernetics and Biomedical Engineering, Volume 41, Issue 2, 2021, Pages 419-444, ISSN 0208-5216, <https://doi.org/10.1016/j.bbe.2021.03.002>.
3. M, Ganesh Kumar, and Agam Das Goswami. 2023. "Automatic Classification of the Severity of Knee Osteoarthritis Using Enhanced Image Sharpening and CNN" Applied Sciences 13, no. 3: 1658. <https://doi.org/10.3390/app13031658>
4. E. Siggstedt, "Machine learning for automatic grading of knee osteoarthritis from X-ray radiographs," Dissertation, 2023.
5. Xuan A, Chen H, Chen T, et al. The application of machine learning in early diagnosis of osteoarthritis: a narrative review. Therapeutic Advances in Musculoskeletal Disease. 2023;15. doi:10.1177/1759720X231158198
6. Hu J, Zheng C, Yu Q, Zhong L, Yu K, Chen Y, Wang Z, Zhang B, Dou Q, Zhang X. DeepKOA: a deep-learning model for predicting progression in knee osteoarthritis using multimodal magnetic resonance images from the osteoarthritis initiative. Quant Imaging Med Surg. 2023 Aug 1;13(8):4852-4866. doi: 10.21037/qims-22-1251. Epub 2023 Jun 2. PMID: 37581080; PMCID: PMC10423358.
7. KELLGREN JH, LAWRENCE JS. Radiological assessment of osteo-arthrosis. Ann Rheum Dis. 1957 Dec;16(4):494-502. doi: 10.1136/ard.16.4.494. PMID: 13498604; PMCID: PMC1006995.
8. Vijaya Kishore V, V. Kalpana, G Hemanth Kumar, Evaluating the efficacy of deep learning models for knee osteoarthritis prediction based on Kellgren-Lawrence grading system, e-Prime - Advances in Electrical Engineering, Electronics and Energy, Volume 5, 2023, 100266, ISSN 2772-6711, <https://doi.org/10.1016/j.prime.2023.100266>.
9. Durán Olivar, David, Automatic detection of knee joints and classification of knee osteoarthritis severity from plain radiographs using CNNs, Universitat Oberta de Catalunya (UOC), Jan-2022, <http://hdl.handle.net/10609/139427>
10. Ozkan Cigdem, Cem M Deniz, Artificial intelligence in knee osteoarthritis: A comprehensive review for 2022, Osteoarthritis Imaging, Volume 3, Issue 3, 2023, 100161, ISSN 2772-6541, <https://doi.org/10.1016/j.ostima.2023.100161>.
11. Tiwari A, Poduval M, Bagaria V. Evaluation of artificial intelligence models for osteoarthritis of the knee using deep learning algorithms for orthopedic radiographs. World J Orthop. 2022 Jun 18;13(6):603-614. doi: 10.5312/wjo.v13.i6.603. PMID: 35949704; PMCID: PMC9244962.
12. Lee, J.; Chung, S.W. Deep Learning for Orthopedic Disease Based on Medical Image Analysis: Present and Future. Appl. Sci. 2022, 12, 681. <https://doi.org/10.3390/app12020681>
13. Pauline Shan Qing Yeoh, Khin Wee Lai, Siew Li Goh, Khairunnisa Hasikin, Yan Chai Hum, Yee Kai Tee, Samiappan Dhanalakshmi, Emergence of Deep Learning in Knee Osteoarthritis Diagnosis, Article in Computational Intelligence and Neuroscience, published November 2021, Computational Intelligence in Image and Video Analysis, Volume 2021 | Article ID 4931437 | <https://doi.org/10.1155/2021/4931437>
14. Lespasio MJ, Piuzzi NS, Husni ME, Muschler GF, Guarino AJ, Mont MA. Knee osteoarthritis: a primer. The Permanente Journal. 2017;21.
15. Abdullah, S.S., Rajasekaran, M.P. Automatic detection and classification of knee osteoarthritis using a deep learning approach. Radiol med 127, 398–406 (2022). <https://doi.org/10.1007/s11547-022-01476-7>
16. C. Kokkotis, S. Moustakidis, E. Papageorgiou, G. Giakas, D.E. Tsaopoulos, Machine learning in knee osteoarthritis: A review, Osteoarthritis and Cartilage Open, Volume 2, Issue 3, 2020, 100069, ISSN 2665-9131, <https://doi.org/10.1016/j.ocarto.2020.100069>.





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17. Li W, Xiao Z, Liu J, Feng J, Zhu D, Liao J, Yu W, Qian B, Chen X, Fang Y, Li S. Deep learning-assisted knee osteoarthritis automatic grading on plain radiographs: the value of multiview X-ray images and prior knowledge. *Quant Imaging Med Surg.* 2023 June 1;13(6):3587-3601. doi: 10.21037/qims-22-1250. Epub 2023 Mar 30. PMID: 37284121; PMCID: PMC10239991.
18. Yoon, J.S., Yon, C.J., Lee, D. et al. Assessment of a novel deep learning-based software developed for automatic feature extraction and grading of radiographic knee osteoarthritis. *BMC MusculoskeletDisord* 24, 869 (2023). <https://doi.org/10.1186/s12891-023-06951-4>
19. Wani, I.M., Arora, S. Osteoporosis diagnosis in knee X-rays by transfer learning based on convolution neural network. *Multimed Tools Appl* 82, 14193–14217 (2023). <https://doi.org/10.1007/s11042-022-13911-y>
20. Quinsten, A.S., Umutlu, L., Forsting, M. et al. Determining the anatomical site in knee radiographs using deep learning. *Sci Rep* 12, 3995 (2022). <https://doi.org/10.1038/s41598-022-08020-7>
21. Ahmed, S.M.; Mstafa, R.J. Identifying Severity Grading of Knee Osteoarthritis from X-ray Images Using an Efficient Mixture of Deep Learning and Machine Learning Models. *Diagnostics* 2022, 12, 2939. <https://doi.org/10.3390/diagnostics12122939>
22. Lee, Hung-Chun et al. "Automatic Assessment of Knee Osteoarthritis Parameters from Two-Dimensional X-ray Image." *First International Conference on Innovative Computing, Information and Control - Volume I (ICICIC'06) 2* (2006): 673-676.
23. F.W. Roemer, A. Guermazi, S. Demehri, W. Wirth, R. Kijowski, *Imaging in Osteoarthritis, Osteoarthritis and Cartilage*, Volume 30, Issue 7, 2022, Pages 913-934, ISSN 1063-4584, <https://doi.org/10.1016/j.joca.2021.04.018>.
24. Pongsakonpruttikul, N & Angthong, Chayanin & Kittichai, Veerayuth & Chuwongin, S & Puengpipattrakul, P & Thongpat, P & S, Boonsang & Tongloy, Teerawat. (2022). Artificial intelligence assistance in radiographic detection and classification of knee osteoarthritis and its severity: a cross-sectional diagnostic study. *European review for medical and pharmacological sciences.* 26. 1549-1558. 10.26355/eurrev_202203_28220.
25. Xia Wang, Win Min Oo, James M Linklater, what is the role of imaging in the clinical diagnosis of osteoarthritis and disease management? *Rheumatology*, Volume 57, Issue suppl_4, May 2018, Pages iv51–iv60, <https://doi.org/10.1093/rheumatology/kex501>
26. Sun, H., Wang, W., He, F. et al. An AI-Based Image Quality Control Framework for Knee Radiographs. *J Digit Imaging* 36, 2278–2289 (2023). <https://doi.org/10.1007/s10278-023-00853-6>
27. Li, Wei & Xiao, Zhongli & Liu, Jin & Feng, Jiaxin & Zhu, Dantian & Liao, Jianwei & Yu, Wenjun & Qian, Baoxin & Chen, Xiaojun & Fang, Yijie & Li, Shaolin. (2023). Deep learning-assisted knee osteoarthritis automatic grading on plain radiographs: the value of multiview X-ray images and prior knowledge. *Quantitative Imaging in Medicine and Surgery.* 13. 10.21037/qims-22-1250.
28. L. Gossec, J.M. Jordan, S.A. Mazzuca, M.-A. Lam, M.E. Suarez-Almazor, J.B. Renner, M.A. Lopez-Olivo, G. Hawker, M. Dougados, J.F. Maillefert, Comparative evaluation of three semi-quantitative radiographic grading techniques for knee osteoarthritis in terms of validity and reproducibility in 1759 X-rays: report of the OARSI-OMERACT task force: Extended report, *Osteoarthritis and Cartilage*, Volume 16, Issue 7, 2008, Pages 742-748, ISSN1063-4584, <https://doi.org/10.1016/j.joca.2008.02.021>.
29. A. Rehman, A. Raza, F. S. Alamri, B. Alghofaily and T. Saba, "Transfer Learning-Based Smart Features Engineering for Osteoarthritis Diagnosis from Knee X-Ray Images," in *IEEE Access*, vol. 11, pp. 71326-71338, 2023, doi: 10.1109/ACCESS.2023.3294542.
30. Schiratti JB, Dubois R, Herent P, Cahané D, Dachary J, et al. A deep learning method for predicting knee osteoarthritis radiographic progression from MRI. *Arthritis Res Ther* 2021;23(1):262.
31. Y. Wang, X. Wang, T. Gao, L. Du, and W. Liu, an automatic knee osteoarthritis diagnosis method based on deep learning: data from the osteoarthritis initiative, *J Healthcare Eng*, vol. 5586529, 2021.
32. Kondal S, Kulkarni V, Gaikwad A, Kharat A, Pant A, et al. Automatic grading of knee osteoarthritis on the Kellgren-Lawrence scale from radiographs using
33. convolutional neural networks. *Advances in Deep Learning, Artificial Intelligence and Robotics Lecture Notes in Networks and Systems* 2022;249:163–73.
34. Tiulpin A, Thevenot J, Rahtu E, Lehenkari P, Saarakkala S, et al. Automatic knee osteoarthritis diagnosis from plain radiographs: a deep learning-based approach. *Sci Rep* 2018;8(1):1727.





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35. Kokkotis C, Ntakolia C, Moustakidis S, Giakas G, Tsaopoulos D, et al. Explainable machine learning for knee osteoarthritis diagnosis based on a novel fuzzy feature selection methodology. *Phys Eng Sci Med* 2022;45 (1):219–29.
36. McCabe PG, Lisboa P, Baltzopoulos B, Olier I. Externally validated models for first diagnosis and risk of progression of knee osteoarthritis. *PLoS One* 2022;17 (7):e0270652.
37. Liu B, Luo J, Huang H. Toward automatic quantification of knee osteoarthritis severity using improved faster R-CNN. *Int J Comput Assist Radiol Surg* 2020;15 (3):457–66.
38. Lim J, Kim J, Cheon S. A deep neural network-based method for early detection of osteoarthritis using statistical data. *Int J Environ Res Public Health* 2019;16(7):1281.
39. Tiulpin A, Klein S, Bierma-Zeinstra SMA, Jérôme T, Esa R, et al. Multimodal machine learning-based knee osteoarthritis progression prediction from plain radiographs and clinical data. *Sci Rep* 2019;9(1):20038.
40. Tolpadi AA, Lee J, Padoia V, Majumdar S. Deep learning predicts total knee replacement from magnetic resonance images. *Sci Rep* 2020;10(1):6371.
41. Russakovsky O, Deng J, Su H, Krause J, Satheesh S, et al. Imagenet large scale visual recognition challenge. *Int J Comput Vis* 2015; 115:211–52.
42. Pan SJ, Yang Q. A survey on transfer learning. *IEEE Trans Knowl Data Eng* 2009; 22:1345–59.
43. OpenCV: “Image thresholding”. [Online]. Available: https://docs.opencv.org/master/d7/d4d/tutorial_py_thresholding.html (Last access on 26/11/2022).
44. Adnan M, Rahman F, Imrul M, Zahid NAL, Shabnam S. Handwritten Bangla character recognition using inception convolutional neural network. *Int J Comput Appl* 2018;181(17):48–59.
45. Lecun Y, Bottou L, Bengio Y, Haffner P. Gradient-based learning applied to document recognition. *Proc IEEE* 1998;86(11):2278–324
46. P. Zhou, B. Ni, C. Geng, J. Hu, and Y. Xu, “Scale-transferable object detection,” in *Proc. 2018 IEEE/CVF Conference on Computer Vision and Pattern Recognition*, Salt Lake City, UT, USA, pp. 528-537, 2018.
47. Tiulpin A, Saarakkala S, Automatic grading of individual knee osteoarthritis features in plain radiographs using deep convolutional neural networks, arXiv preprint arXiv:1907.08020; 2019.

Table. 1 Comparison of different ML associated PPD models

Schiratti et al. [30]	Deep learning	AUC 65%
Wang et al. [31]	CNN and YOLOv2	Accuracy: 69.18%.
Kondal et al. [32]	CNN	Accuracy:87%
Tiulpin et al. [33]	CNN	Accuracy: 66.71% and ROC curve of 0.93
Kokkotis et al. [34]	Random Forest	Accuracy: 73.55%
McCabe et al. [35]	LR and Cox regression	AUC: 0.67 for the validation data and 0.75 for the test data.
Liu et al. [36]	RPN and Fast R-CNN	sensitivity above 78% and specificity above 94%
Lim et al. [37]	CNN	AUC: 76.8%
Tiulpin et al. [38]	CNN	Precision: 0.62 and AUC: 0.8
Tolpadi et al. [39]	deep Siamese CNN and a refined ResNet-34	Accuracy: 61%
Sameh Abd El-Ghany et al. [1]	DenseNet169	Accuracy: 95.93





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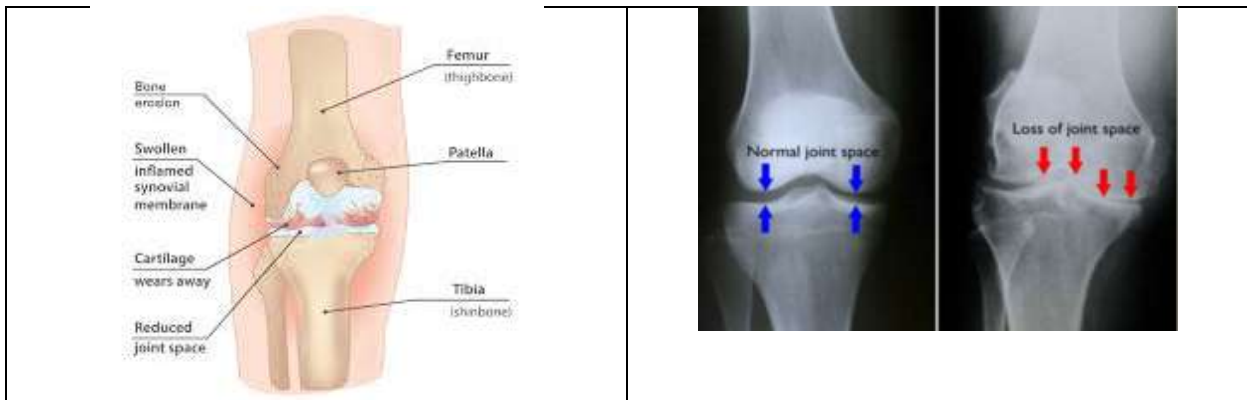


Fig 1: Compartments of a knee with their names.



Fig 2: Normal vs Loss of joint space of X-ray image of the knee

a) Normal joint space x-ray Image b) Loss of joint space x-ray Image.

K/L Grade	Grade 0	Grade 1	Grade 2	Grade 3	Grade 4
Sample Images					
Classification	Normal	Doubtful	Mild	Moderate	Severe
Description	No features of OA	Minimal Osteophytes; Doubtful alignment	Definite Osteophytes; Normal Joint Space	Moderate joint space reduction	Joint Space greatly reduced; subchondral sclerosis

Fig 3: Stage of Knee OA [2]





Use of Artificial Intelligence (AI) for Pesticide Detection: A Case Study-based Approach

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ABSTRACT

Pesticides are extensively utilized in agriculture to increase productivity, forbid crop damage from weeds and pests, and combat vector-borne diseases. However, they pose significant health risks, including asthma, reduced lung and thyroid function, and infertility. These chemicals can enter the body through inhalation, ingestion, or skin contact, causing symptoms and issues such as coughing, breathing difficulties, and heart problems. The accumulation of pesticides in aquatic animals, bottled water, cow milk, and mother's milk through biomagnification is a global concern. Numerous research papers have examined pesticide pollution and its impact on human health, highlighting the need for accelerated and affordable methods to estimate pesticide levels. Artificial Intelligence has become increasingly important in agriculture. The management decision and support systems being used to schedule crop management activities, leading to reduced pesticide, herbicide, and water usage. This is summarised in graphical abstract (fig.1). This review explores the application of AI in crop cultivation, particularly in pesticide use, implementation challenges, and its future scope in this area. In this research paper a case study-based approach, highlighting the use of drones to guide farmer decisions is presented.

Keywords: Artificial Intelligence, Pesticides, Drones, Soil and water Pollution, Biosensors, Environment



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INTRODUCTION

To combat harmful pests from damaging crops and its products, farmers heavily rely on the usage of synthetic pesticides. However, due to the prolonged persistence of these pesticides in the environment leads to adverse impacts on human health and environment. Farmers handle pesticides regularly than and are hence at a higher risk of exposure to them. Such exposure generally happens when farmers prepare and apply the pesticide sprays, or when they clean the spraying equipment. In these processes, farmers may be exposed to chemicals due to spills, faulty gear, or direct spray contact caused by the lack of protective gear. Additionally, farmers who engage in manual labour on pesticide-treated fields may encounter significant exposure through spraying directly, drifting from neighbouring fields, or contact with pesticide residues on the crops or soil, even if they are not directly working with pesticides[1].As represented in Figure2, these noxious compounds have been implicated in the proliferation of various forms of pollution, including but not limited to water pollution, air pollution, soil pollution, and even noise pollution. The chemical residues of pesticides can persist in the environment for prolonged periods, leading to bioaccumulation in organisms, biomagnification in food chains, and consequent toxicity at higher trophic levels. The myriads of negative impacts stemming from pesticide contamination can manifest in a wide range of ecological and public health consequences, including ecosystem degradation, biodiversity loss, cancer, and other chronic diseases. Pesticide production began in India near Kolkata in 1952, and currently India is the second-largest producer of pesticides in Asia, after China. However, there lies a difference in the pattern of pesticide usage by India and rest of the world [2]. For quite some time now, the issue of pesticide-induced human poisoning has been considered a significant public health concern.State governments have a limited amount of authority to regulate pesticides under the Insecticides Act. Regulating body provide licences to companies to manufacture, sell, stock or exhibit for sale or distribute pesticides. If a safety issue occurs, the Act allows states to impose a 60-day pesticide ban, with possible 30-day extensions. In addition to the Insecticides Act, the states of Punjab, Kerala, and Sikkim have created additional state-level legislation for pesticide regulation and have restricted the use of Highly Hazardous Pesticides (HHP) through this method. Figure 3 gives the state-wise usage of pesticides in India[3].

In the year 1990, the World Health Organization (WHO) task force calculated that approximately one million unintentional pesticide poisonings occur every year, causing severe symptoms and resulting in around 20,000 fatalities. The impact of pesticide poisoning is felt most acutely by individuals in developing nations, and it is likely that the actual number of cases is much higher since many cases are not reported [4], [5]. Table 1 represents the pesticide classification by WHO. Every year, an astounding amount of 150,000 tons of fertilizers and 6,000 tons of pesticides are regularly used to boost agricultural production [6]. The main way the public encounters pesticides is by consuming food and water that has been infected with pesticides and its residues. As for the negative impact on the surroundings, various factors can impact the severity of effect ssuch as the pesticide toxicity, application methods, precautions taken, the amount applied, the extent of adsorption to soil colloids, the weather conditions post-application, and the duration for which the pesticide is present in surroundings. These effects can manifest contamination in air, water and soil through spray drift, leaching, runoff, as well as terrible harm to wildlife, fish, plants, and other such non-target organisms through biomagnification [7]. Pesticides are classified based on their chemical composition and the pest they are intended to control. Table 2 gives the major categories of pesticides including Pyrethroids, Organochlorine, Organophosphates, Soil Fumigants, Triazines, Carbamates, and Neonicotinoid Pesticides. Table also, describes the impacts of the pesticides on human health and their Lethal Dose (LD) value. LD value, also known as LD50, is a measure of acute toxicity used to estimate the lethal dose of a substance that can cause death in 50% of the population or test animals exposed to it. The agricultural industry heavily depends on the use of pesticides nowadays. Therefore, building trust and supporting farmers requires acknowledging the necessity of modifying pesticide usage. This can be achieved through implementing new or existing technologies such as artificial intelligence that enhance efficiency, decrease costs, and enable effective decision-making [6].





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Artificial Intelligence

The feigning of human intelligence in machines, programmed in such a way that it can think, reason, even learn just as humans, is referred as Artificial Intelligence (AI). It includes the construction of algorithms and computer programs having the ability of performing the given tasks usually requiring human intelligence. The tasks can involve recognition of speech, interpretation of complex data sets, and making of decisions based on that data. With the rapid advancements in technology and increasing availability of data, AI is becoming increasingly sophisticated and is expected to play an exponentially increasing significant role in shaping our future [8]. Alan Turing, an English computer scientist and mathematician, is extensively considered as one of the pioneers of AI. His paper [9] published way back in 1950, proposed a test to check if a machine can exhibit behaviour that cannot be differentiated it from a human, now commonly known as the Turing Test. Turing's work was the steppingstone for the development of AI, along with its major components such as cognitive computing, natural language processing as well as machine learning. His ideas and contributions have been the subject of many studies and research papers in various fields, including computer science, philosophy, and cognitive psychology. Turing's legacy in the field of AI is also evident in the development of modern computing and artificial intelligence systems, such as the Turing machine and the Turing-complete programming language. Overall, Turing's work has a profound impact on AI and continues to inspire researchers worldwide [10][11]. Figure 4 represents what all AI can entail. The two types include Weak or Narrow AI and Strong or General AI [12].

Artificial Narrow Intelligence (ANI) includes

AI systems that are created to perform required tasks within a limited range of functions. These AI systems are not capable of performing tasks outside of their designed purpose. Some of the classic examples of narrow AI are the virtual assistants such as Siri or Alexa, image recognising systems and chatbots used in security cameras or self-driving cars [13].

Artificial General Intelligence is a hypothetical form of AI that would have human-level intelligence and would be able to perform any intellectual task that humans can. This type of AI has not yet been achieved, but research continues in this field [14]. Figure 5 represents the use of AI by general population. Wide range of applications are performed by AI across various fields. Figure 6 presents the various applications of AI. Here are few examples:

1. **Healthcare:** AI has been used in the diagnosis of various diseases. A study published in Nature Medicine used machine learning to diagnose autism spectrum disorder from brain scans with high accuracy [15].
2. **Finance:** AI is being used in the finance industry for fraud detection, portfolio management, and risk assessment. [16].
3. **Transportation:** AI has been used in the field of transportation for autonomous driving, traffic prediction, and route optimisation. A thorough investigation into the subject is available in a publication [17].
4. **Manufacturing:** AI is being used to streamline operations, cut downtime, and enhance quality assurance [18].

The next section is discussing in detail the role of AI in agriculture

AI and Agriculture

A lot of manual labour has been required in agriculture, but modern AI technology allows farmers to quickly and accurately assess their crops on a large and detailed scale, reducing the need for human engagement.

The use of AI in agriculture, as seen in Figure 7, has the potential to completely alter how we raise and produce food. Several research papers are reviewed for AI application in agriculture. Few applications are listed below

1. **Crop Monitoring:** AI is used to monitor crops, including disease detection and crop yield estimation. In a recent study, deep learning was used to forecast crop yields and identify the key factors that affect crop output [19].
2. **Precision Agriculture:** AI is being used for precision agriculture, including seed selection, crop management, and soil analysis. A recent study used machine learning to identify optimal planting patterns for corn crops, resulting in higher yields and reduced costs. [20].





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3. **Harvesting:** AI is being used for harvesting, including automated fruit picking and sorting. A recent study used AI to develop a robotic system for apple harvesting, which resulted in higher productivity and reduced labor costs [21].
4. **Pest Control:** AI is being used for pest control, including the detection and prevention of pest infestations. A recent study used machine learning to detect and classify pest infestations in tomato crops, resulting in improved pest control and reduced costs [22].
5. **Irrigation Management:** AI is being used for irrigation management, including water conservation and crop health. A recent study used machine learning to optimize irrigation scheduling for tomato crops, resulting in improved crop yields and reduced water use [23]. Hence, the utilization of AI in agriculture has the capability to improve crop yields, reduce costs, and promote sustainable farming practices. In the next section AI and Pesticide Detection is discussed in detail.

AI and Pesticide Detection

Over time, there have been huge increases in the use of pesticides in agriculture, raising worries about the environment and health associated consequences. It is essential to find pesticide residues in crops and soil to maintain environmental sustainability and food safety. However, traditional approaches to pesticide detection are time-consuming, expensive, and call for a high level of technical knowledge. This has boosted interest in creating AI-based pesticide detection systems that are quick and precise [24]. Detection of pesticide residues in soil and crops, as well as the forecasting of pesticide leaching and runoff, have all been addressed by AI-based systems. To create prediction models for pesticide detection, deep learning, support vector machines (SVMs), and artificial neural networks are being used. These algorithms accurately identify and categorise pesticide residues using a variety of data types, such as spectral, chemical, and gene expression data [25]. The ability of AI-based systems to analyse enormous amounts of data rapidly and reliably is one of their primary advantages for pesticide detection. Models for identifying pesticide residues in crops and soil have been developed using spectral data, which has been gathered through methods like mass spectrometry and infrared spectroscopy. The development of portable on-site testing instruments made possible by the use of AI-based pesticide detection systems has made it simpler and quicker to find pesticide residues in crops and soil [26]. Additionally, AI-based algorithms have been used to forecast pesticide runoff and leaching. Algorithms for machine learning consider a number of variables, including application rate, soil type, and weather. These models help farmers come to informed conclusions and take relevant measures concerning the use of pesticides, their reduction, and their environmental impact [27]. Despite the potential advantages of AI-based systems for the detection of pesticides, there are certain restrictions and difficulties as well. To guarantee the security and effectiveness of AI-based systems for pesticide detection, however, there are regulatory and legislative concerns that must be resolved [28]. The detection of pesticide residues in crops and soil, as well as the forecasting of pesticide leaching and runoff, are important applications for AI-based systems. Rapid and precise identification of pesticide residues can be achieved by the application of machine learning algorithms and spectral data analysis, enabling the more efficient and environmentally friendly use of pesticides in agriculture [26], [27].

In next section a case study is discussed to showcase the use of drone in pesticide detection.

Case Study: Pesticide Detection Through Drones

An unmanned aerial vehicle (UAV), commonly known as Drone. Drone can fly autonomously or can be flown remotely through flight plans controlled by software. They can carry various sensors and cameras, making them useful in many applications, including agriculture [29]. AI algorithms can be used to process the data collected by drones and provide insights into the distribution of pesticides on crops.

Components of Drones

Drones are complex machines that consist of various components that enable their functionality. The components of drones can vary depending on their intended use and complexity. However, some essential components of drones are presented in figure 8(Karar et al. 2021).

1. **Frame:** The drone's frame, also known as its structural body, binds all the parts together. Depending on the design of the drone, it may be constructed from a variety of materials such as metal, carbon fibre, or plastic.





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2. **Motors:** Drone are propelled in the air by its motors. A drone's design and size, determine the number of motors in it. While some drones have six or eight motors, whereas majority have four only.
3. **Propellers:** The thrust required to lift the drone into the air is produced by the motors' accompanying propellers. They are chosen based on the weight and drone design.
4. **Flight controller:** It serves as the drone's "brain" and is in charge of determining the drone's flight route, stability, and orientation. Gyroscopes, accelerometers, and barometer sensors are used to measure the drone's position and modify its flight.
5. **Battery:** The drone's power comes from its battery, which also supplies the power needed to run its motors, flight controller, and other parts. The size and design of the drone will determine battery capacity and size.
6. **Camera:** Many drones are equipped with cameras that enable the capture of aerial images and videos. Aside from monitoring, the camera can also be used for mapping and photography. The crops and surroundings are captured in-depth in still photos or films by the camera. Experts can visually examine the plants using these images to look for symptoms of pesticide harm, such as discoloration, wilting, or pest infestation. They also get a thorough perspective of the agricultural landscape. The high resolution of the camera makes it easier to spot minute alterations or irregularities that might not be readily apparent from ground level inspections.
7. **GPS:** The GPS receiver identifies the drone's location and its path of travel. It can also be used to enclose a drone in a virtual barrier to prevent it from circling outside of a specific area.

Applications of Drones in Pesticides Scheduling

Traditional methods of pesticide detection entail taking samples from the crops and testing them in a lab. Pesticides are often applied across a vast area of crops. This procedure is time-consuming, costly, and it might not give information regarding the distribution of pesticides in real-time [27]. But pesticide application may be done more effectively and economically with drones [29]. These drones are well equipped with variety of sensors, thermal cameras and hyperspectral cameras that can provide helpful data regarding the distribution of pesticides on crops, enabling farmers to make relevant decisions regarding the usage of pesticides. The sensors present in drone provide high-resolution photos and data that can be processed using artificial intelligence (AI) to identify the regions of the crop where the pesticide is more concentrated. Several recent studies have demonstrated the effectiveness of using drones in pesticide detection [32]-[34]. The two real time tried applications include:

1. **Pesticide spraying drone:** The product showed satisfactory results when tested on paddy and groundnut fields. The technology incorporated in drone was a spray motor. [35]
2. **Pesticide and fertilizer spraying drone:** The technology incorporated in drone was Arduino, Gyroscope sensor and accelerometer [36]. Again, these types of drones are less manpower and time consuming.

Advantages of using Drones

A growing number of farmers are turning to drones because of their potential to boost output and efficiency while cutting costs. The following are some benefits of drone, also shown in Figure 9 in agriculture: [37]-[39]:

1. **Precision Agriculture:** Drones are equipped with numerous sensors. High-resolution data, such as crop height, plant count, and vegetation index, can be gathered using these sensors. With the aid of these information, farmers can apply fertilisers, insecticides, and herbicides precisely where they are needed, this minimizes the wastage of chemical and also leads to increase in crop output [40].
2. **Time Saving:** Traditional crop monitoring and mapping techniques need more time and labour than drones, whereas drones can quickly cover enormous regions. This can assist farmers in promptly seeing problems in their farms and taking prompt action to fix them [41].
3. **Cost-Effective:** Drone use has the potential to be more economical than conventional agricultural monitoring techniques like manned aircraft or manual labour. They can lower expenses linked with crop monitoring and inputs like fertilisers, insecticides, and herbicides by providing timely and precise data for crop management decisions [42].
4. **Safety:** Drone use can increase agricultural workers and farmers safety by decreasing hazardous chemical exposure and the requirement for physical labour in hazardous environments.





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5. **Environmental Sustainability:** By enabling accurate administration of fertilisers, insecticides, and herbicides, drones can assist farmers in minimising their environmental impact. By doing so, the quantity of chemicals required, and the danger of chemical runoff and soil erosion can both be reduced [29].

Challenges faced in using Drone Technology

This cutting-edge technology not only provides solutions to the agricultural sector but also help in resolving the problems of other industries. In order to utilize the drone fully there are few issues associated with their practical applications should be resolved. Figure 9 depicts the challenges faced in drone technology [43]-[46].

1. **Expenditure:** Farmers frequently face considerable obstacles due to the high cost of drone procurement and maintenance, especially when used on a small scale. Additionally, farmers may encounter difficulties using drones due to a lack of technological skills.
2. **Data Analysis:** To properly use the data gathered by the drones, high-quality data processing is required, which presents another problem. Farmers may find the amount of data collected to be overwhelming, and processing and interpreting it may call for specialised software and qualified employees.
3. **Weather Conditions:** The use of drones in agriculture may also be impacted by weather conditions. Extreme cold or hot temperatures, wind, or rain might create difficult for the drone to fly and gather reliable data.
4. **Security and Privacy:** Drone use in agriculture raise few additional privacy issues. The position and configuration of crops are the sensitive photographs and data that the drones may record. This raises questions regarding data ownership and privacy. Drones can be used to monitor the effectiveness of pesticide application. Overall, the use of drones in pesticide detection could revolutionize agriculture by informing farmers with real-time information about the distribution of pesticides on crops. This information further guides the farmers make reliable and informed decisions about the usage of these pesticides, reduction in risk of overuse and minimization of the environmental consequences brought about by them [36].

COMPARISON WITH TRADITIONAL METHODS

Accuracy Analysis

Visual examination and sample collections are the mainstays of conventional pest detection techniques, however both techniques can be sensitive to human error. The level of knowledge and experience of the persons engaged determines how accurate the detection is carried out. In one of the research study the pesticide spray deposition efficiency was evaluated by using Unmanned Aerial Vehicle (UAV) with boom sprayer against Conventional Knapsack Sprayers to control wheat aphids in wheat fields. The result of the study indicates that UAV with boom sprayer is more efficient than conventional method in controlling Aphids [47].

Cost Analysis

With traditional techniques, employees physically inspect crops, spot insect infestations, and schedule the administration of pesticides. This procedure is expensive, labour-intensive, and time-consuming. 30% of the pesticide is saved while spraying because of the high level of atomization. All stages of the crop can be sprayed with pesticides in the form of chemical fog. Compared to traditional spraying methods, drones consume 90% less water because to their ultra-low volume spraying technology. Overall, using drones for spraying is 97% less expensive than using traditional spraying methods. [48]. The drones used in agriculture are tough. It requires less maintenance, has a long useful life, and its parts are easy to replace as needed for the business providing drone services. Because of their cost-effectiveness, drones are increasingly being used for pesticide detection and scheduling. Targeted pesticide applications are made possible by drones that are fitted with specialised sensors and cameras that can gather data rapidly and effectively.

IMPLEMENTATION CHALLENGES

AI could revolutionize the agriculture industry, from crop management to livestock monitoring, to supply chain optimization. However, the implementation of AI in agriculture comes with challenges. Some of those implementation challenges of AI in agriculture include [49]





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1. **Data Collection and Management:** The availability and calibre of data represent one of the major obstacles to AI application in agriculture. Data collection and management in agriculture can be challenging, but AI models need a lot of data to train and optimise their algorithms. Farmers might lack the infrastructure needed to successfully collect and preserve data, and data quality can vary depending on the source. Additionally, there may be restrictions on data sharing between farmers, researchers, and other stakeholders, which impedes the creation of thorough and efficient AI models. [50]
2. **Infrastructure and Connectivity:** The connectivity and infrastructure needed for the implementation of AI provide another difficulty. To process and analyse data in real-time, AI models need strong processing capabilities and fast internet. However, it may be challenging to adopt AI technology in many rural locations due to a lack of the required infrastructure.
3. **Cost:** It can be expensive to use AI in agriculture, especially for small-scale farmers. It can be expensive to purchase AI gear and software, which makes it challenging for farmers to use the technology.
4. **Lack of Technical Skills:** AI implementation also requires technical expertise, which may not be readily available in the agriculture industry. Farmers may lack the technical skills needed to implement as well as maintain AI systems, making it difficult to fully realize the benefits of AI.
5. **Ethical Concerns:** Aside from the possible negative effects on labour markets and data security, there are ethical issues with AI use in agriculture. To ensure that the use of AI in agriculture is ethical as well as long-lasting, these issues must be addressed [51].

CONCLUSION AND FUTURE PROSPECTS

Artificial intelligence is a fast-expanding field with a lot of potential to boost productivity and efficiency across a wide range of industries, including agriculture. Artificial intelligence is being used in agriculture for a variety of tasks, including soil analysis, irrigation control, harvesting, weather forecasting, and crop monitoring and management. By 2050, it is expected that there will be 9.8 billion people on the planet, which would increase the demand for food [52]. AI has the potential to help meet this demand by optimizing agricultural production and increasing crop yields. Precision agriculture, which uses technology to precisely target crops with inputs like fertiliser, herbicides, and water to optimise their development and production, is an important application of AI in agriculture. For instance, machine learning systems might examine sensor data and satellite photos to identify stressed fields and modify inputs accordingly. Higher crop yields and more effective resource usage may result from this. Drones with AI capabilities can also assist farmers in identifying crop health issues early on and responding fast, minimising crop losses. Plant breeding is another area of agriculture where AI is being used. Machine learning is being used by researchers to study plant genetics and forecast which traits will produce successful crops. This can aid plant breeders in creating new varieties of plants that are more resistant to pests and the changing climate. AI is also being utilised to support farmers in making better choices for their cultivation, its management, and its harvest. AI, for instance, can assess weather data to determine when it is optimal to plant and harvest crops. Software with AI capabilities can also be used by farmers to monitor soil health, manage irrigation, and consume less water. By using these technologies, farmers may increase the general productivity of their fields and make better judgements. The lack of infrastructure and technological availability in rural areas is a major barrier to the widespread use of AI in agriculture. It's possible that many farmers lack access to high-speed internet, or the gear required to run AI-powered products. To assist farmers in implementing new technology, governments and commercial organisations must make investments in infrastructure development and training programmes[53]. Artificial intelligence (AI) could transform agriculture by boosting crop yields, decreasing resource waste, and enhancing decision-making. Before adopting, however, there are still certain major issues that must be resolved.

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REFERENCES

1. C. A. Damalas and S. D. Koutroubas, "Farmers' Exposure to Pesticides: Toxicity Types and Ways of Prevention," *Toxics*, vol. 4, no. 1, Jan. 2016, doi: 10.3390/TOXICS4010001.
2. W. Aktar, D. Sengupta, and A. Chowdhury, "Impact of pesticides use in agriculture: their benefits and hazards," *Interdiscip Toxicol*, vol. 2, no. 1, pp. 1–12, Mar. 2009, doi: 10.2478/V10102-009-0001-7.
3. T. Bonvoisin, L. Utyasheva, D. Knipe, D. Gunnell, and M. Eddleston, "Suicide by pesticide poisoning in India: A review of pesticide regulations and their impact on suicide trends," *BMC Public Health*, vol. 20, no. 1, pp. 1–16, Feb. 2020, doi: 10.1186/S12889-020-8339-Z/TABLES/3.
4. J. Jeyaratnam, R. S. De Alwis Seneviratne, and J. F. Copplestone, "Survey of pesticide poisoning in Sri Lanka," *Bull World Health Organ*, vol. 60, no. 4, p. 615, 1982, Accessed: Mar. 29, 2023. [Online]. Available: /pmc/articles/PMC2536079/?report=abstract
5. W. Boedeker, M. Watts, P. Clausing, and E. Marquez, "The global distribution of acute unintentional pesticide poisoning: estimations based on a systematic review," *BMC Public Health* 2020 20:1, vol. 20, no. 1, pp. 1–19, Dec. 2020, doi: 10.1186/S12889-020-09939-0.
6. H. M. Isah, H. O. Sawyerr, M. O. Raimi, and B. G. Bashir, "Assessment of Commonly Used Pesticides and Frequency of Self-Reported Symptoms on Farmers Health in Kura, Kano State, Nigeria," *Journal of Education and Learning Management*, vol. 1, no. 1, pp. 31–54, 2020, doi: 10.46410/JELM.2020.1.1.05.
7. C. A. Damalas and I. G. Eleftherohorinos, "Pesticide Exposure, Safety Issues, and Risk Assessment Indicators," *Int J Environ Res Public Health*, vol. 8, no. 5, p. 1402, 2011, doi: 10.3390/IJERPH8051402.
8. I. M. Cockburn et al., "The Impact of Artificial Intelligence on Innovation," 2018, Accessed: Mar. 29, 2023. [Online]. Available: <http://www.nber.org/papers/w24449>
9. A. M. TURING, "I.—COMPUTING MACHINERY AND INTELLIGENCE," *Mind*, vol. LIX, no. 236, pp. 433–460, Oct. 1950, doi: 10.1093/MIND/LIX.236.433.
10. K. Warwick and H. Shah, "Turing's Ideas on Machine Thinking and Intelligence," *Turing's Imitation Game*, pp. 23–40, Oct. 2016, doi: 10.1017/CBO9781107297234.003.
11. M. B. Fazi, "Can a machine think (anything new)? Automation beyond simulation," *AI & SOCIETY* 2018 34:4, vol. 34, no. 4, pp. 813–824, Feb. 2018, doi: 10.1007/S00146-018-0821-0.
12. A. G. Ranade, M. Patel, and A. Magare, "Emotion model for artificial intelligence and their applications," *PDGC 2018 - 2018 5th International Conference on Parallel, Distributed and Grid Computing*, pp. 335–339, Dec. 2018, doi: 10.1109/PDGC.2018.8745840.
13. C. Beaulac and F. Larribe, "Narrow artificial intelligence with machine learning for real-time estimation of a mobile agent's location using hidden markov models," *International Journal of Computer Games Technology*, vol. 2017, 2017, doi: 10.1155/2017/4939261.
14. B. Goertzel, "Artificial General Intelligence: Concept, State of the Art, and Future Prospects," *Journal of Artificial General Intelligence*, vol. 5, no. 1, pp. 2013–2015, 2014, doi: 10.2478/jagi-2014-0001.
15. M. Liu, B. Li, and D. Hu, "Autism Spectrum Disorder Studies Using fMRI Data and Machine Learning: A Review," *Front Neurosci*, vol. 15, Sep. 2021, doi: 10.3389/FNINS.2021.697870.
16. V. Aithal and R. D. Jathanna, "Credit risk assessment using machine learning techniques," *International Journal of Innovative Technology and Exploring Engineering*, vol. 9, no. 1, pp. 3482–3486, Nov. 2019, doi: 10.35940/IJITEE.A4936.119119.
17. L. Kuang, X. Yan, X. Tan, S. Li, and X. Yang, "Predicting Taxi Demand Based on 3D Convolutional Neural Network and Multi-task Learning," *Remote Sensing 2019, Vol. 11, Page 1265*, vol. 11, no. 11, p. 1265, May 2019, doi: 10.3390/RS11111265.
18. A. Jamwal, R. Agrawal, and M. Sharma, "Deep learning for manufacturing sustainability: Models, applications in Industry 4.0 and implications," *International Journal of Information Management Data Insights*, vol. 2, no. 2, p. 100107, Nov. 2022, doi: 10.1016/J.IJIMEI.2022.100107.





Kriti Ahuja et al.,

19. S. M. SAMPTKUMARI BANDAGAR Asst Professor, "CROP AND SOIL MONITORING BY ARTIFICIAL INTELLIGENCE TECHNIQUE," *International Journal for Research Trends and Innovation*, vol. 7, pp. 2456–3315, 2022, Accessed: Mar. 30, 2023. [Online]. Available: www.ijrti.org
20. M. Javaid, A. Haleem, I. H. Khan, and R. Suman, "Understanding the potential applications of Artificial Intelligence in Agriculture Sector," *Advanced Agrochem*, vol. 2, no. 1, pp. 15–30, Mar. 2023, doi: 10.1016/J.AAC.2022.10.001.
21. T. U. Sane and T. U. Sane, "Artificial Intelligence and Deep Learning Applications in Crop Harvesting Robots-A Survey," *3rd International Conference on Electrical, Communication and Computer Engineering, ICECCE 2021*, Jun. 2021, doi: 10.1109/ICECCE52056.2021.9514232.
22. S. Kathuria, "Pest Detection Using Artificial Intelligence," *International Journal of Science and Research*, doi: 10.21275/SR201216152858.
23. D. Sinwar, V. S. Dhaka, M. K. Sharma, and G. Rani, "AI-Based Yield Prediction and Smart Irrigation," pp. 155–180, 2020, doi: 10.1007/978-981-15-0663-5_8.
24. Y. N. Chen, K. C. Fan, Y. L. Chang, and T. Moriyama, "Special Issue Review: Artificial Intelligence and Machine Learning Applications in Remote Sensing," *Remote Sensing 2023, Vol. 15, Page 569*, vol. 15, no. 3, p. 569, Jan. 2023, doi: 10.3390/RS15030569.
25. R. D. Clark, "Putting deep learning in perspective for pest management scientists," *Pest Manag Sci*, vol. 76, no. 7, p. 2267, Jul. 2020, doi: 10.1002/PS.5820.
26. Y. Chen, H. Dou, Q. Chang, and C. Fan, "PRIAS: An Intelligent Analysis System for Pesticide Residue Detection Data and Its Application in Food Safety Supervision," *Foods 2022, Vol. 11, Page 780*, vol. 11, no. 6, p. 780, Mar. 2022, doi: 10.3390/FOODS11060780.
27. T. Talaviya, D. Shah, N. Patel, H. Yagnik, and M. Shah, "Implementation of artificial intelligence in agriculture for optimisation of irrigation and application of pesticides and herbicides," *Artificial Intelligence in Agriculture*, vol. 4, pp. 58–73, Jan. 2020, doi: 10.1016/J.AIIA.2020.04.002.
28. "AI in Agriculture: Challenges, Benefits, and Use Cases - Intellias." Accessed: Jan. 01, 2023. [Online]. Available: <https://intellias.com/artificial-intelligence-in-agriculture/>
29. S. Ahirwar, R. Swarnkar, S. Bhukya, and G. Namwade, "Application of Drone in Agriculture," *Int J Curr Microbiol Appl Sci*, vol. 8, no. 01, pp. 2500–2505, Jan. 2019, doi: 10.20546/ijcmas.2019.801.264.
30. M. E. Karar, F. Alotaibi, A. Al Rasheed, and O. Reyad, "A pilot study of smart agricultural irrigation using unmanned aerial vehicles and IoT-based cloud system," *Information Sciences Letters*, vol. 10, no. 1, pp. 131–140, 2021, doi: 10.18576/ISL/100115.
31. "Schematic diagram of the proposed smart irrigation system using IoT and... | Download Scientific Diagram." Accessed: Mar. 30, 2023. [Online]. Available: https://www.researchgate.net/figure/Schematic-diagram-of-the-proposed-smart-irrigation-system-using-IoT-and-a-drone_fig4_348231055
32. J. G. A. Barbedo, "A Review on the Use of Unmanned Aerial Vehicles and Imaging Sensors for Monitoring and Assessing Plant Stresses," *Drones 2019, Vol. 3, Page 40*, vol. 3, no. 2, p. 40, Apr. 2019, doi: 10.3390/DRONES3020040.
33. T. Zhang et al., "Using Machine Learning and Hyperspectral Images to Assess Damages to Corn Plant Caused by Glyphosate and to Evaluate Recoverability," *Agronomy 2021, Vol. 11, Page 583*, vol. 11, no. 3, p. 583, Mar. 2021, doi: 10.3390/AGRONOMY11030583.
34. K. Neupane and F. Baysal-Gurel, "Automatic Identification and Monitoring of Plant Diseases Using Unmanned Aerial Vehicles: A Review," *Remote Sensing 2021, Vol. 13, Page 3841*, vol. 13, no. 19, p. 3841, Sep. 2021, doi: 10.3390/RS13193841.
35. D. Yallappa, M. Veerangouda, D. Maski, V. Palled, and M. Bheemanna, "Development and evaluation of drone mounted sprayer for pesticide applications to crops," *GHTC 2017 - IEEE Global Humanitarian Technology Conference, Proceedings*, vol. 2017-January, pp. 1–7, Dec. 2017, doi: 10.1109/GHTC.2017.8239330.
36. I.D. Pharne, S. Kanase, S. Patwegar, P. Patil, A. Pore, & Y. Kadam, Y. (2018) "Agriculture drone sprayer". *International Journal of Recent Trends in Engineering & Research (IJRTER)*, vol. 4 (3), pp.181-185.





Kriti Ahuja et al.,

37. M. Alsamarraie, F. Ghazali, Z. M. Hatem, and A. Y. Flaih, "A REVIEW ON THE BENEFITS, BARRIERS OF THE DRONE EMPLOYMENT IN THE CONSTRUCTION SITE," *J Teknol*, vol. 84, no. 2, pp. 121–131, Mar. 2022, doi: 10.11113/JURNALTEKNOLOGI.V84.17503.
38. R. Kellermann, T. Biehle, and L. Fischer, "Drones for parcel and passenger transportation: A literature review," *Transp Res Interdiscip Perspect*, vol. 4, Mar. 2020, doi: 10.1016/j.trip.2019.100088.
39. H. TUROĞLU, "The Advantages Of Drone Technology In Urban Flood Studies," *International Symposium On Geomorphology, Proceedings Book (Ululararasi Jeomorfoloji Sempozyumu, Bildiriler Kitabı)*, no. January 2019, pp. 611–619, Jan. 2017, Accessed: Mar. 30, 2023. [Online]. Available: https://www.academia.edu/38674751/The_Advantages_Of_Drone_Technology_In_Urban_Flood_Studies
40. A. Nayyar and L. Raja, "Agriculture drones: A modern breakthrough in precision agriculture Resource Scheduling View project Sensor Based m-health System View project", doi: 10.1080/09720510.2017.1395171.
41. K. A. Johannessen, "A Conceptual Approach to Time Savings and Cost Competitiveness Assessments for Drone Transport of Biologic Samples with Unmanned Aerial Systems (Drones)," *Drones 2022, Vol. 6, Page 62*, vol. 6, no. 3, p. 62, Feb. 2022, doi: 10.3390/DRONES6030062.
42. V. Partel, S. Charan Kakarla, and Y. Ampatzidis, "Development and evaluation of a low-cost and smart technology for precision weed management utilizing artificial intelligence," *Comput Electron Agric*, vol. 157, pp. 339–350, Feb. 2019, doi: 10.1016/J.COMPAG.2018.12.048.
43. R. Majeed, N. A. Abdullah, M. F. Mushtaq, and R. Kazmi, "Drone Security: Issues and Challenges," *International Journal of Advanced Computer Science and Applications*, vol. 12, no. 5, pp. 720–729, 2021, doi: 10.14569/IJACSA.2021.0120584.
44. S. A. H. Mohsan, N. Q. H. Othman, Y. Li, M. H. Alsharif, and M. A. Khan, "Unmanned aerial vehicles (UAVs): practical aspects, applications, open challenges, security issues, and future trends," *Intelligent Service Robotics 2023 16:1*, vol. 16, no. 1, pp. 109–137, Jan. 2023, doi: 10.1007/S11370-022-00452-4.
45. S. Oleksyn, L. Tosoletto, V. Raoult, K. E. Joyce, and J. E. Williamson, "Going Batty: The Challenges and Opportunities of Using Drones to Monitor the Behaviour and Habitat Use of Rays," *Drones 2021, Vol. 5, Page 12*, vol. 5, no. 1, p. 12, Feb. 2021, doi: 10.3390/DRONES5010012.
46. M. Deja, M. S. Siemitkowski, G. C. Vosniakos, and G. Maltezos, "Opportunities and challenges for exploiting drones in agile manufacturing systems," *Procedia Manuf*, vol. 51, pp. 527–534, Jan. 2020, doi: 10.1016/J.PROMFG.2020.10.074.
47. G. Wang et al., "Comparison of Spray Deposition, Control Efficacy on Wheat Aphids and Working Efficiency in the Wheat Field of the Unmanned Aerial Vehicle with Boom Sprayer and Two Conventional Knapsack Sprayers," *Applied Sciences*, vol. 9, no. 2, p. 218, Jan. 2019, doi: 10.3390/APP9020218.
48. H. Pathak, G. Kumar, S. D. Mohapatra, B. B. Gaikwad, and J. Rane, "Use of Drones in Agriculture: Potentials, Problems and Policy Needs".
49. A. Subeesh and C. R. Mehta, "Automation and digitization of agriculture using artificial intelligence and internet of things," *Artificial Intelligence in Agriculture*, vol. 5, pp. 278–291, Jan. 2021, doi: 10.1016/J.AIIA.2021.11.004.
50. "ficci: Use of AI, tech can address challenges in Indian agriculture sector, says new report - The Economic Times." Accessed: Jan. 01, 2023. [Online]. Available: <https://economictimes.indiatimes.com/news/economy/agriculture/use-of-ai-tech-can-address-challenges-in-indian-agriculture-sector-says-new-report/articleshow/91945030.cms?from=mdr>
51. R. Mark, "Ethics of Using AI and Big Data in Agriculture: The Case of a Large Agriculture Multinational," *The ORBIT Journal*, vol. 2, no. 2, pp. 1–27, Jan. 2019, doi: 10.29297/ORBIT.V2I2.109.
52. U. Nations, "World population projected to reach 9.8 billion in 2050, and 11.2 billion in 2100 | United Nations", Accessed: Apr. 02, 2023. [Online]. Available: <https://www.un.org/en/desa/world-population-projected-reach-98-billion-2050-and-112-billion-2100>
53. S. Saurabh, "Poverty and Literacy Status of the Indian States: Group Differential Measures," *SSRN Electronic Journal*, Apr. 2009, doi: 10.2139/SSRN.1392005.
54. A. M. Ramchandra, B. Chacko, and P. J. Victor, "Pyrethroid Poisoning," *Indian J Crit Care Med*, vol. 23, no. Suppl 4, p. S267, 2019, doi: 10.5005/JP-JOURNALS-10071-23304.





Kriti Ahuja et al.,

55. R. Jayaraj, P. Megha, and P. Sreedev, "Organochlorine pesticides, their toxic effects on living organisms and their fate in the environment," *Interdiscip Toxicol*, vol. 9, no. 3–4, p. 90, Dec. 2016, doi: 10.1515/INTOX-2016-0012.
56. W. T. Tsai, "Organochlorine Insecticides," *Encyclopedia of Toxicology: Third Edition*, pp. 711–713, Jan. 2014, doi: 10.1016/B978-0-12-386454-3.00172-X.
57. A. Adeyinka, E. Muco, and L. Pierre, "Organophosphates," *Hazardous Chemicals: Agents of Risk and Change, 1800-2000*, pp. 267–293, Sep. 2022, doi: 10.5005/jp/books/11606_36.
58. D. O. Chellemi, "Plant Health Management: Soil Fumigation," *Encyclopedia of Agriculture and Food Systems*, pp. 456–459, Jan. 2014, doi: 10.1016/B978-0-444-52512-3.00250-3.
59. H. Nagami and T. Suenaga, "[Health Effects Caused by Soil Fumigant Chloropicrin, Reduction of Exposure to Chloropicrin, and Alternative Technology of Soil Fumigants]," *J UOEH*, vol. 44, no. 4, pp. 395–404, 2022, doi: 10.7888/JUOEH.44.395.
60. R. T. Mandelbaum, M. J. Sadowsky, and L. P. Wackett, "Microbial Degradation of s-Triazine Herbicides," *The Triazine Herbicides*, pp. 301–328, Jan. 2008, doi: 10.1016/B978-044451167-6.50025-8.
61. J. Silberman and A. Taylor, "Carbamate Toxicity," *StatPearls*, May 2022, Accessed: Mar. 30, 2023. [Online]. Available: <https://www.ncbi.nlm.nih.gov/books/NBK482183/>
62. N. Haddaji, "Environmental contaminants and antibiotic resistance as a One Health threat," *One Health: Integrated Approach to 21st Century Challenges to Health*, pp. 231–252, Jan. 2022, doi: 10.1016/B978-0-12-822794-7.00010-1.
63. M. L. Hladik, A. R. Main, and D. Goulson, "Environmental Risks and Challenges Associated with Neonicotinoid Insecticides," *Environ Sci Technol*, vol. 52, no. 6, pp. 3329–3335, Mar. 2018, doi: 10.1021/ACS.EST.7B06388/ASSET/IMAGES/LARGE/ES-2017-063888_0002.JPEG.
64. S. Ensley, "Imidacloprid," *Veterinary Toxicology: Basic and Clinical Principles*, pp. 505–507, Mar. 2007, doi: 10.1016/B978-012370467-2/50141-3.

Table 1: Various pesticide used and their hazardous class ((Akashe et al. 2018)

Pesticide usage	Active Ingredient	Main Use	Hazardous Class as per WHO
Atrazine	Triazines	Herbicides	III
Sevin	Carbaryl (Carbamate)	Insecticides	II
Primextra	S-Metolachlor (chloroacetanilide)	Herbicides	Not Known
Fusilade	Fluazifop-p-βutyl (aryloxyphenoxypropionate)	Herbicides	III
Thiodan	Endosulfan (organochlorine)	Insecticide	II
Apron Plus	Metalaxyl (phenylamide)	Fungicide	II
Polythrine	Cypermethrin (pyrethroids)	Insecticides	II

Table 2: Different classes of pesticides and their health effects

S.no.	Category of Pesticide	Impact on Health	Common Examples in market	LD ₅₀ Value	Reference
1	Pyrethroids	Accidental exposure to of permethrin may lead to symptoms like headache, nausea, fatigue, stinging, itching and dizziness.	Permethrin (Biomist®), resmethrin (Scourge®).	0.5 mg/kg to 250 mg/kg	[54]
2	Organochlorine	Short term exposure may	DDT, dieldrin, methoxychlor,	1 mg/kg to	[55],[56]





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		cause tremors, headaches, slurred speech, salivation and sweating. Long term exposure may cause significant effect to liver, kidneys and central nervous system. It had also been known to have increased the rate of kidney and liver cancer.	chlordane, mirex, lindane, chlordane, and toxaphene.	10 mg/kg	
3	Organophosphates (Nerve gas)	It can lead to leukaemia, seizures, excessive sweating, distorted vision, lacrimation and salivation	Chlorpyrifos, Diazinone, Dichlorvos, Sarin, Soman and Phosmet	<50 mg/kg	[57]
4	Soil Fumigants	Mild to severe eye pain, headache, sore throat and even premature birth	Propylene oxide, methyl bromide, dichloropropane, propylene oxide, and dibromochloropropane	691.83 mg/kg	[58], [59]
5	Triazenes	Abdominal pain, diarrhoea, vomiting, dermatitis, skin rash, and mild to severe irritation and redness in eyes.	Ametryn, Prometryn, Propazine, Cyanazine and Prometon	2000 mg/kg	[60]
6	Carbamates	Headache, Dizziness, Nausea, Weakness, Diarrhoea and skin rash	Terbucarb, Carbaryl, Propuxer, Oxamyl and Carbaryl	285 mg/kg to 7500 mg/kg	[61], [62]
7	Neonicotinoid pesticides	It is capable of causing Breast Cancer and severe effects during developmental period.	Clothiniandin, Imidacloprid, Acetamiprid and Thiamethoxam	475 mg/kg to 5,000 mg/kg	[63], [64]

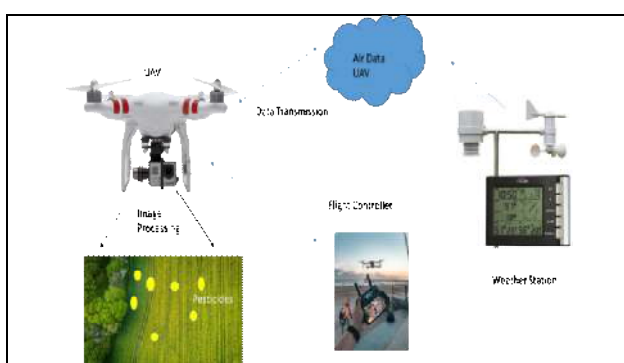


Figure 1: Diagrammatic representation of UAV (an AI model) detecting pesticide

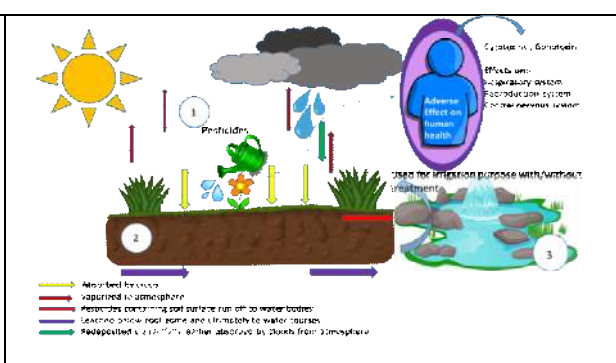


Figure 2: Diagrammatic representation in health effects due to Pesticide





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<p>Figure 3: Use of Pesticide in India</p>	<p>Figure 4: What AI entails?</p>
<p>Figure 5: AI as used in General Population</p>	<p>Figure 6: Various Applications of AI</p>
<p>Figure 7: Various Applications of AI in Agriculture</p>	<p>Figure 8: Different components of UAV</p>
<p>Figure 9: Advantages and Disadvantages of Drone in Pesticide Scheduling and Detection</p>	





A Study of Psychological Issues and Gen Z's Education and Lifestyle Suffering

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ABSTRACT

The article aims to talk about the psychological impact of COVID-19 on the daily routines of human lives. The pandemic created a shift in human behaviour and a growing sense of laziness and lethargy in their daily lives. Before COVID-19, laziness did not prevail among people widely, but due to the pandemic, laziness became a habit. Before COVID-19, people had busy lives and personal responsibilities, often giving them little time for rest. However, with the growing technological advancements, people started to rely on them. Many individuals rely on digital devices and delivery services. The broad impact of technology on how kids grow up has made each generation more independent than the last and each generation's life path slower. The goal of the article is to show the everyday psychological effects of pandemic and suffering by looking at Gen Z's way of life. Further, it traces how students and their education are affected.

Keywords: Everyday Pandemic, Gen Z's Sufferings, Slowness in daily life, Impact on COVID 19, Changes in Education , psychological suffering.

INTRODUCTION

The daily routines involved all sorts of technological advancements, and that is when they started contributing to a sense of laziness and slowness. The COVID-19 pandemic brought significant changes in daily routines. With lockdowns, social distancing, and working from home, people spent more time in their homes and less engaging in



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physical activities. The gyms, parks, and outdoor spaces were closed, so people had no physical activities or social interactions. Due to quarantine, individuals started developing slowness, which increased laziness. The increase in laziness also causes psychological health issues. They create stress and instability, and the isolation caused by the virus plays a vital role in the mental health of human beings. Many individuals experienced depression and anxiety, and it all contributed to the lack of motivation.

The wide reliance on the technology due to the pandemic has increased the laziness. There were various platforms through which human beings found their entertainment, like social media platforms, streaming services, and online entertainment options, etc.; all this increased laziness, and people were spending hours glued to their screens instead of engaging in physical activities or pursuing meaningful hobbies. However, laziness did not affect the personal hygiene of human beings; people became more conscious about personal hygiene, regularly washing their hands and sanitizing frequently.

The students were also affected by laziness; their learning process changed, and they were learning through virtual classrooms. The change to online platforms often led to feelings of disconnection and isolation, making it harder for them to stay motivated. Due to this, the students became lethargic and lost focus on their studies. Students started feeling tempted to procrastinate and started prioritizing leisure activities over their academics. But we cannot blame anyone for laziness because it's quite challenging for people to be demotivated. We must be able to get ourselves back on track again. When the pandemic was over, people started their daily routines. However, laziness still seems to prevail among people because it has become a habit for everyone to procrastinate and deviate from their responsibilities. Even after the pandemic, the effects of laziness, procrastination, and sedentary activities seem to prevail, but we must eradicate them before they become inevitable. It is now time for people to start realizing and creating a new routine that will save them from being slow, sluggish, and lazy.

REVIEW OF LITERATURE

According to Angeletti (2023), *The Decameron* is one of the most important pieces of Giovanni Boccaccio's collection that speaks about the black death. Wray states (2004) The black death, a devastating pandemic that swept across Europe in the mid-14th century! Had profound and far-reaching effects. Estimates suggest the black death wiped out 25 - 50 %. Europe's demand for labour increased. It challenged the existing social order dominated by nobility and landowners. Trade routes were disrupted due to fear of contagion, and overall economic activity declined. The rapid spread of the disease and the high mortality rate caused widespread fear and despair. In *A Journal of the Plague Year*, Daniel Defoe gives a fictionalized account of the great plague of London in 1665, offering a chillingly realistic Portrayal of the social and psychological impact of the epidemic.

According to Shannon & Cromley (2013), The Great Plague of London lasted from 1665 to 1666 and was England's last major bubonic plague outbreak. It was a devastating event that claimed the lives of an estimated 100000 people, nearly a quarter of London's population at the time. The rapid spread of the disease overwhelmed the city's resources. The 2009 H1N1 Virus emerged in Mexico and quickly spread worldwide, reaching pandemic status within a few months. The pandemic caused significant economic disruptions due to travel restrictions, school closures, and business shutdowns. The global cost of the pandemic was estimated to be in the trillion USD due to swine flu slowness. In history, Marcus Aurelius's rule, the last few years of the pandemic, are often called the "golden age" of Rome. In those days, there were about 75 million people living in the Roman Empire. That's about a quarter of all people on Earth. The number of people living in the Roman Empire went up around the time of the Antonine Plague and then began to go down. It was the right time for an outbreak, even though the Roman Empire's economy was doing well.

The people were not healthy. About 20% of the people lived in one of the hundreds of towns, which was a big share by ancient standards. Rome, with an estimated one million people, was the biggest. City dwellers lost a lot of people,



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even when things were good. The death rate was higher than the birth rate, so new people had to move into cities all the time to keep the population stable. The normal life expectancy at birth was only in the mid-twenties because more than half of children died before they turned 18. Disease was more likely to spread in cities with lots of people and bad drainage. There were land and sea links between the Roman Empire's many areas. This made it easier and faster for infectious diseases to spread from one area to another than in smaller, less connected societies. The empire had a lot of epidemics of contagious diseases. Between 43 BC and 148 AD, nine were reported. Even the wealthy could be affected by the bad weather. Emperor Marcus Aurelius had fourteen children, but only two are known to have grown up.

Mental slowness in the lives of Gen Z

A lot of people just call this group "Gen Z." It comes after the Millennials and before group Alpha. They're also called "Zoomers." The mid- to late-1990s serve as the years of birth that start and end the project for both experts and the public. Generation Z is mostly made up of kids from Generation X or older Millennials.

As Harari, Tali Te'eni, et al. (2020) say, Gen Z spends less time talking to people face-to-face. This may be one reason why they are the group that reports being depressed the most. New studies show that the COVID-19 virus has had a big effect on the mental health of Generation I. Students still have a lot of problems with their mental health. People from the older group are more likely to say they feel anxious, stressed, sad, and alone. The Gen I Care group is becoming the most difficult problem to solve at work, according to the research. They deal with stress, anxiety, and not knowing what the future holds. They say negative things, but they don't really feel bad feelings. The Internet is a great way to learn new things and get ideas from anywhere in the world. All Gen Z kids' mental health is affected by electronics and social media. They go to the class—a honest tom—and learn what it's like to lose something.

A lot of people in Gen Z no longer see the point in going to college. A poll by BI/YouGov found that only 39% of them think it's important to get more schooling. The poll found that only 39% of Gen Z thought it was important to get more education, and 46% thought college wasn't worth the money. This is also true for schooling. Like on social media, Gen Z students want to get comments right away on their work. They also want to be able to choose how they are educated. Students want to be able to choose what they learn and how they show what they know. Generation Z is dealing with more stress than any other generation before them. One clear cause of the rise in stress among Generation Z is the constant pressure they feel at school. In a world where the job market is very competitive and school standards are rising, young people are often stuck in a never-ending race to do well. While their drive to be successful is admirable, it hurts their mental health and puts a huge load on them from a very young age. Gen Z is worried about money and getting things they want.

If you don't get rich quickly and spend time with your family, you might get a bad reputation. Every Gen Zer has a beautiful dream that they want to make come true. It's a dream of many to change the past, forget old things, and make new ones. These two fears are linked by one thing: Time: To use or keep time. How successful Gen Z is depends on how much time they have. They are learning how to make good use of their time because Gen Z would make them much more productive.

CONCLUSIONS

Based on what we've talked about so far, we know that the pandemic makes people lazy, less likely to go to school, less likely to interact with others, and less likely to care about others. Since COVID-19 causes a pandemic in the world, it's our job to fight laziness. Self-motivation is also important if we want to talk to our friends about anything. Then we can get out of this pandemic problem. We can't do anything until we fully understand your situation and the current state and effects of COVID-19. This will take a lot of sacrifice. Don't be lazy and think about the past, though. We're lucky to be alive now. Move on. It will help you have a great life. They think they can't find the answer





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on their own, but everyone else can. We shouldn't think that way. Instead, we should have faith in ourselves and do our best to get through every outbreak.

REFERENCES

1. Angeletti, Valerio. "From Plague to Plague: COVID-19 and the New Decameron(S)." *International Social Science Journal*, vol. 74, no. 251, May 2023, pp. 25–36. DOI: 10.1111/issj.12434.
2. Connor, Henry. "Defoe's Journal of the Plague Year: A Study of Risk Management." *Journal of the Royal Society of Medicine*, vol. 113, no. 12, Oct. 2020, pp. 504–05. DOI: 10.1177/0141076820962060.
3. Harari, Tali Te'eni, et al. "Gen Z During the COVID-19 Crisis: A Comparative Analysis of the Differences Between Gen Z and Gen X in Resilience, Values and Attitudes." *Current Psychology*, vol. 42, no. 28, Aug. 2022, pp. 24223–32. DOI: 10.1007/s12144-022-03501-4.
4. Shannon, Gary, and Robert Cromley. "THE GREAT PLAGUE OF LONDON, 1665." *Urban Geography*, vol. 1, no. 3, July 1980, pp. 254–70. DOI:10.2747/0272-3638.1.3.254.
5. Wray, Shona. "Boccaccio and the Doctors: Medicine and Compassion in the Face of Plague." *Journal of Medieval History*, vol. 30, no. 3, Sept. 2004, pp. 301–22. DOI: 10.1016/j.jmedhist.2004.06.005.





A MCDM Method based on Aggregation Operators under Cubic Root Fuzzy Sets

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ABSTRACT

In this article, we present the new notion of cubic root fuzzy sets and we defined different operators such that Union, Intersection, Complement, Score Function, Accuracy Function and Cubic Root Fuzzy Weighted Average operator(CRFWA), Cubic Root Fuzzy Weighted Geometric operator(CRFWG), Cubic Root Fuzzy Weighted Power Average operator(CRFWPA), Cubic Root Fuzzy Weighted Power Geometric operator(CRFWPG). Furthermore, we present MCDM Problem and an algorithm based on aggregation operators for cubic root fuzzy set.

Keywords: Cubic Root Fuzzy Set, Score Function, Accuracy Function, Aggregation operators, CRFWA, CRFWG, CRFWPA, CRFWPG, MCDM.

INTRODUCTION

A concept of fuzzy set (FS) introduced by Zadeh. Atanassov generalized FS developed by Intuitionistic Fuzzy set (IFS)[1] and then Yager further improve the quantity by bringing out the Pythagorean fuzzy set (PFS). PFS[2] explains vagueness by the use of the MD function δ and NMD function γ where their square sum lies between 0 and 1, (i.e) $0 < \delta^2 + \gamma^2 < 1$. Fermatean fuzzy[6] set have been validated as new of the tools to address uncertain information. Senapati and Yagar outlined basic operator over FFS. In this article, we study the notion of Cubic fuzzy Sets(CR Fuzzy set), score function, accuracy function and aggregation operations such as Cubic Root Fuzzy Weighted Average operator(CRFWA), Cubic Root Fuzzy Weighted Geometric





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operator(CRFGW), Cubic Root Fuzzy Weighted Power Average operator(CRFWPA), Cubic Root Fuzzy Weighted Power Geometric operator(CRFWPG) and algorithm based on aggregation operations for cubic root fuzzy set can be used in the MCDM method with suitable example[3].

Preliminary

Definition: Fermatean Fuzzy set [6]

A Fermatean fuzzy set (FFS) F in U an object having the form $F = [x, \delta(x), \gamma(x)/x \in U]$, where δ_F, γ_F represents the MD and NMD of F respectively. The mapping $\delta_F, \gamma_F: U \rightarrow [0,1]$ and $0 \leq \delta_F^3 + \gamma_F^3 \leq 1$ and also defined by the degree of indeterminacy function

$$\pi_F = \sqrt[3]{1 - [\delta^3 + \gamma^3]}, \text{ for all } x \in U.$$

Definition: Cubic Root Fuzzy Set[4]

Let U be a universal set and the element is denoted by y . Then the Cubic Root Fuzzy Set (CR-Fuzzy Set) of R is defined as, $R = [y, \delta(y), \gamma(y)/y \in X]$, where δ_R, γ_R represents the MD and NMD of R respectively. The mapping $\delta_R, \gamma_R: U \rightarrow [0,1]$ and $\leq \delta_R^3 + \sqrt{\gamma_R} \leq 1$. and also defined by the degree of indeterminacy function $\pi_R(x) =$

$$\sqrt[3]{1 - \delta_R^3 + \sqrt{\gamma_R}}$$

Definition: (6).

Let $R = [\delta, \gamma], R_1 = [\delta_1, \gamma_1]$ and $R_2 = [\delta_2, \gamma_2]$ be the Cubic Root fuzzy sets and $\lambda \geq 0$, then the following operators hold

- (i) $R_1 \oplus R_2 = (\sqrt[3]{\delta_1^3 + \delta_2^3 - \delta_1^3 \delta_2^3}, (\gamma_1 \gamma_2))$
- (ii) $R_1 \otimes R_2 = ((\delta_1 \delta_2), \sqrt[3]{\gamma_1^{1/2} + \gamma_2^{1/2} - \gamma_1^{1/2} \gamma_2^{1/2}})$
- (iii) $\lambda R = (\sqrt[3]{1 - (1 - \delta^3)^\lambda}, \gamma^\lambda)$
- (iv) $R^\lambda = (\delta^\lambda, \sqrt[3]{1 - (1 - \gamma^{1/2})^\lambda})$

Theorem

Let R, R_1 and R_2 and $\lambda_1, \lambda_2 \geq 0$ the following hold

- (i) $R_1 \oplus R_2 = R_2 \oplus R_1$
- (ii) $R_1 \otimes R_2 = R_2 \otimes R_1$
- (iii) $\lambda(R_1 \oplus R_2) = \lambda R_1 \oplus \lambda R_2$
- (iv) $(\lambda_1 \oplus \lambda_2)R = \lambda_1 R \oplus \lambda_2 R$
- (v) $R^{\lambda_1} \otimes R^{\lambda_2} = R^{\lambda_1 + \lambda_2}$

Proof: For three cubic root fuzzy number R, R_1 and R_2 and $\lambda_1, \lambda_2 < 0$, according to definition, we obtain,

$$\begin{aligned} \text{(i)} \quad R_1 \oplus R_2 &= (\sqrt[3]{\delta_1^3 + \delta_2^3 - \delta_1^3 \delta_2^3}, (\gamma_1 \gamma_2)) \\ &= (\sqrt[3]{\delta_2^3 + \delta_1^3 - \delta_2^3 \delta_1^3}, (\gamma_2 \gamma_1)) \\ &= R_2 \oplus R_1 \\ \text{(ii)} \quad R_1 \otimes R_2 &= ((\delta_1 \delta_2), \sqrt[3]{\gamma_1^{1/2} + \gamma_2^{1/2} - \gamma_1^{1/2} \gamma_2^{1/2}}) \\ &= ((\delta_2 \delta_1), \sqrt[3]{\gamma_2^{1/2} + \gamma_1^{1/2} - \gamma_2^{1/2} \gamma_1^{1/2}}) \end{aligned}$$





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$$\begin{aligned}
 &= R_2 \otimes R_1 \\
 R_1 \otimes R_2 &= R_2 \otimes R_1 \\
 \text{(iii)} \quad \lambda(R_1 \oplus R_2) &= \lambda(\sqrt[3]{\delta_1^3 + \delta_2^3 - \delta_1^3 \delta_2^3}, (\gamma_1 \gamma_2)) \\
 &= \sqrt[3]{1 - (1 - \delta_1^3 - \delta_2^3 + \delta_1^3 \delta_2^3)^\lambda}, (\gamma_1 \gamma_2)^\lambda \\
 &= \sqrt[3]{1 - (1 - \delta_1^3)^\lambda (1 - \delta_2^3)^\lambda}, (\gamma_1^\lambda \gamma_2^\lambda) \text{L.H.S} \\
 \lambda R_1 \oplus \lambda R_2 &= (\sqrt[3]{1 - (1 - \delta_1^3)^\lambda} \gamma_1^\lambda \oplus \sqrt[3]{1 - (1 - \delta_2^3)^\lambda} \gamma_2^\lambda) \dots R.H.S \\
 \lambda(R_1 \oplus R_2) &= \lambda R_1 \oplus \lambda R_2
 \end{aligned}$$

$$\begin{aligned}
 \text{(iv)} \quad (\lambda_1 \oplus \lambda_2)R &= (\sqrt[3]{1 - (1 - \delta^3)^{(\lambda_1 \oplus \lambda_2)}}, \gamma^{(\lambda_1 \oplus \lambda_2)}) \\
 &= \sqrt[3]{1 - (1 - \delta^3)^{(\lambda_1 \oplus \lambda_2)} (1 - \delta^3)^{(\lambda_1 \oplus \lambda_2)}}, \gamma^{(\lambda_1 \oplus \lambda_2)} \\
 &= (\sqrt[3]{1 - (1 - \delta^3)^{\lambda_1}}, \gamma^{\lambda_1}) \oplus (\sqrt[3]{1 - (1 - \delta^3)^{\lambda_2}}, \gamma^{\lambda_2}) \\
 &= \lambda_1 R \oplus \lambda_2 R
 \end{aligned}$$

$$\begin{aligned}
 \text{(v)} \quad R^{\lambda_1} \otimes R^{\lambda_2} &= (\delta^{\lambda_1}, \sqrt[3]{1 - (1 - \gamma^{1/2})^{\lambda_1}}) \otimes (\delta^{\lambda_2}, \sqrt[3]{1 - (1 - \gamma^{1/2})^{\lambda_2}}) \\
 &= (\delta^{\lambda_1 \oplus \lambda_2}, \sqrt[3]{1 - (1 - \gamma^{1/2})^{\lambda_1 \oplus \lambda_2}}) \\
 &= R^{\lambda_1 + \lambda_2} \\
 R^{\lambda_1} \otimes R^{\lambda_2} &= R^{\lambda_1 + \lambda_2}
 \end{aligned}$$

Operation of Cubic Root Fuzzy Set

Let $R = [\delta, \gamma], R_1 = [\delta_1, \gamma_1], R_2 = [\delta_2, \gamma_2]$ be the Cubic Root fuzzy sets, then[4]

(i) Intersection:

$$R_1 \wedge R_2 = \min(\delta_1, \delta_2), \max(\gamma_1, \gamma_2)$$

(ii) Union:

$$R_1 \vee R_2 = \max(\delta_1, \delta_2), \min(\gamma_1, \gamma_2)$$

(iii) Complement

$$(R)^c = [(\delta)^6, \sqrt{\gamma}]$$

Note that $(\sqrt[2]{\gamma^6} + \sqrt[4]{\delta^2}) = (\gamma)3 + \sqrt{\delta}$
 $= (0.5)^3 + \sqrt{0.7} = 0.96166 < 1$

so, $(R)^c$ is a Cubic Root fuzzy set.

We know that,

$$(R^c)^c = (\gamma(x)^6, \sqrt[4]{\delta(x)})^c = (\delta(x), \gamma(x)) = R.$$

Example

Assume that $R_1 = (\delta_1=0.67, \gamma_1=0.32)$ and $R_2 = (\delta_2=0.25, \gamma_2=0.74)$ are the Cubic Root fuzzy sets, then

(i) Intersection:

$$\begin{aligned}
 R_1 \wedge R_2 &= \min(\delta_1, \delta_2), \max(\gamma_1, \gamma_2) \\
 &= (\min(0.67, 0.25), \max(0.32, 0.74)) \\
 &= (0.25, 0.74)
 \end{aligned}$$





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(ii) Union:

$$R_1 \vee R_2 = \max(\delta_1, \delta_2), \min(\gamma_1, \gamma_2) \\ = (\max(0.67, 0.25), \min(0.32, 0.74)) \\ = (0.67, 0.32)$$

(iii) Complement

$$(R)^c = [(\delta)^6, \sqrt[6]{\gamma}] \\ = ((0.33)^6, \sqrt[6]{0.67}) \\ = (0.001, 0.81)$$

Definition: (Score Function)[6]

Let $R = (\delta_R, \gamma_R)$ be the CRFS then the score function is defined as

$$S(R) = \delta_R^3 - \sqrt[3]{\gamma_R} \dots\dots(A)$$

and noted that $S(R) \in [-1, 1]$

Example: Let $R = [0.4, 0.8]$ be the CRFS then $S(R) = 0.4^3 - \sqrt[3]{0.8} = -0.830$

Definition: (Accuracy Function)

Let $R = (\delta_R, \gamma_R)$ be the CRFS then the accuracy function is defined as

$$A(R) = \delta_R^3 + \sqrt[3]{\gamma_R} \dots\dots(B)$$

and noted that $A(R) \in [0, 1]$

Example: Let $R = [0.4, 0.8]$ be the CRFS then $A(R) = 0.4^3 + \sqrt[3]{0.8} = 0.958$

Theorem

For three cubic root fuzzy number R, R_1, R_2 and R_3 and $\lambda_1, \lambda_2 < 0$ following are valid

- (i) $R_1 \wedge R_2 = R_2 \wedge R_1$ (ii) $R_1 \vee R_2 = R_2 \vee R_1$
- (iii) $R_1 \wedge (R_2 \wedge R_3) = (R_1 \wedge R_2) \wedge R_3$ (iv) $R_1 \vee (R_2 \vee R_3) = (R_1 \vee R_2) \vee R_3$
- (v) $\lambda(R_1 \vee R_2) = \lambda R_1 \vee \lambda R_2$ (iv) $(R_1 \vee R_2)\lambda = (R_1)\lambda \vee (R_2)\lambda$

Proof:

(i) $R_1 \wedge R_2 = \min(\delta_1, \delta_2), \max(\gamma_1, \gamma_2) \\ = \min(\delta_2, \delta_1), \max(\gamma_2, \gamma_1) \\ = R_2 \wedge R_1$

(ii) $R_1 \vee R_2 = \max(\delta_1, \delta_2), \min(\gamma_1, \gamma_2) \\ = \max(\delta_2, \delta_1), \min(\gamma_2, \gamma_1) \\ = R_2 \vee R_1$

(iii) $R_1 \wedge (R_2 \wedge R_3) = R_1 \wedge (\min(\delta_2, \delta_3), \max(\gamma_2, \gamma_3)) \\ = \min(\delta_1, (\min(\delta_2, \delta_3))), \max(\gamma_1, (\max(\gamma_2, \gamma_3))) \\ = \min((\delta_1, \delta_2), \min \delta_3), (\max(\gamma_1, \gamma_2), \max \gamma_3)) \\ = (\min(\delta_1, \delta_2), \max(\gamma_1, \gamma_2)) \wedge R_3 \\ = (R_1 \wedge R_2) \wedge R_3$

(iv) $R_1 \vee (R_2 \vee R_3) = R_1 \vee (\max(\delta_2(x), \delta_3(x)), \min(\gamma_2(x), \gamma_3(x))) \\ = \max(\delta_1, (\max(\delta_2(x), \delta_3(x))), \min(\gamma_1, (\min(\gamma_2(x), \gamma_3(x)))) \\ = \max((\delta_1, \delta_2(x)), \max \delta_3(x)), (\min(\gamma_1, \gamma_2(x)), \min \gamma_3(x))) \\ = (\max(\delta_1(x), \delta_2(x)), \min(\gamma_1(x), \gamma_2(x))) \vee R_3$





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$$\begin{aligned}
 &= (R_1 \vee R_2) \vee R_3 \\
 \text{(v) } \lambda(R_1 \vee R_2) &= \lambda(\max(\delta_1, \delta_2), \min(\gamma_1, \gamma_2)) \\
 &= \sqrt[3]{1 - (1 - \max(\delta_1^3, \delta_2^3))^\lambda}, \min(\gamma_1^\lambda, \gamma_2^\lambda) \\
 \lambda R_1 \vee \lambda R_2 &= (\sqrt[3]{1 - (1 - \delta_1^3)^\lambda}, \gamma_1^\lambda) \vee (\sqrt[3]{1 - (1 - \delta_2^3)^\lambda}, \gamma_2^\lambda) \\
 &= \max(\sqrt[3]{1 - (1 - \delta_1^3)^\lambda}, \sqrt[3]{1 - (1 - \delta_2^3)^\lambda}, \min(\gamma_1^\lambda, \gamma_2^\lambda)) \\
 &= \sqrt[3]{1 - (1 - \max(\delta_1^3, \delta_2^3))^\lambda}, \min(\gamma_1^\lambda, \gamma_2^\lambda) \\
 &= \lambda(R_1 \vee R_2) \\
 \lambda(R_1 \vee R_2) &= \lambda R_1 \vee \lambda R_2
 \end{aligned}$$

Theorem

For two cubic root fuzzy number $R_1 = (\delta_1, \gamma_1), R_2 = (\delta_2, \gamma_2)$ following are valid

- (i) $(R_1 \wedge R_2) \vee R_2 = R_2$
- (ii) $(R_1 \vee R_2) \wedge R_2 = R_2$

proof:

$$\begin{aligned}
 \text{(i) } (R_1 \wedge R_2) \vee R_2 &= (\min(\delta_1, \delta_2), \max(\gamma_1, \gamma_2)) \vee (\delta_2, \gamma_2) \\
 &= (\max(\min(\delta_1, \delta_2), \delta_2), \min(\max(\gamma_1, \gamma_2), \gamma_2)) \\
 &= (\delta_2, \gamma_2) = R_2 \\
 \text{(ii) } (R_1 \vee R_2) \wedge R_2 &= (\max(\delta_1, \delta_2), \min(\gamma_1, \gamma_2)) \wedge (\delta_2, \gamma_2) \\
 &= (\min(\max(\delta_1, \delta_2), \delta_2), \max(\min(\gamma_1, \gamma_2), \gamma_2)) \\
 &= (\delta_2, \gamma_2) = R_2
 \end{aligned}$$

Theorem

For two cubic root fuzzy number $R_1 = (\delta_1, \gamma_1), R_2 = (\delta_2, \gamma_2)$ following are valid

- (i) $(R_1 \vee R_2)^C = R_1^C \wedge R_2^C$
- (ii) $(R_1 \wedge R_2)^C = R_1^C \vee R_2^C$

Proof:

$$\begin{aligned}
 \text{(i) } (R_1 \vee R_2)^C &= (\max(\delta_1, \delta_2), \min(\gamma_1, \gamma_2))^C \\
 &= (\min((\gamma_1)^6, (\gamma_2)^6), \max(\sqrt{\delta_1}, \sqrt{\delta_2})) \\
 &= ((\gamma_1)^6, \sqrt{\delta_1}) \wedge ((\gamma_2)^6, \sqrt{\delta_2}) \\
 &= R_1^C \wedge R_2^C \\
 \text{(ii) } (R_1 \wedge R_2)^C &= (\min(\delta_1, \delta_2), \max(\gamma_1, \gamma_2))^C \\
 &= (\max((\gamma_1)^6, (\gamma_2)^6), \min(\sqrt{\delta_1}, \sqrt{\delta_2})) \\
 &= ((\gamma_1)^6, \sqrt{\delta_1}) \vee ((\gamma_2)^6, \sqrt{\delta_2}) \\
 &= R_1^C \vee R_2^C
 \end{aligned}$$

Aggregation of Cubic Root Fuzzy Set[6]

Definition:

Let $R_z = (\delta_{R_z}, \gamma_{R_z})$ ($z = 1$ to n) be the Cubic Root Fuzzy Set and $\tau = (\tau_1, \tau_2, \dots, \tau_n)^T$ be the weight vector of R_z with $\sum_{z=1}^n \tau_z = 1$. Then a Cubic Root Fuzzy Weighted Average (CRFWA) operator is a function CRFWA: $R^n \rightarrow R$, where

$$\text{CRFWA}(R_1, R_2, R_3, \dots, R_n) = [\sum_{z=1}^n \tau_z \delta_z, \sum_{z=1}^n \tau_z \gamma_z] \dots \dots \dots (1)$$





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Definition

Let $R_z=(\delta_{R_z}, \gamma_{R_z})$ ($z=1$ to n) be the Cubic Root Fuzzy Set and $\tau = (\tau_1, \tau_2, \dots, \tau_n)^T$ be the weight vector of R_z with $\sum_{z=1}^n \tau_z = 1$. Then a Cubic Root Fuzzy Weighted Geometric (CRFWG) operator is a function CRFWG: $R^n \rightarrow R$, where
 CRFWG $(R_1, R_2, R_3, \dots, R_n) = [\prod_{z=1}^n \delta_z^{\tau_z}, \prod_{z=1}^n \gamma_z^{\tau_z}] \dots \dots \dots (2)$

Definition

Let $R_z=(\delta_{R_z}, \gamma_{R_z})$ ($z=1$ to n) be the Cubic Root Fuzzy Set and $\tau = (\tau_1, \tau_2, \dots, \tau_n)^T$ be the weight vector of R_z with $\sum_{z=1}^n \tau_z = 1$. Then a Cubic Root Fuzzy Weighted Power Average (CRFWPA) operator is a function CRFWPA: $R^n \rightarrow R$, where
 CRFWPA $(R_1, R_2, R_3, \dots, R_n) = [(\sum_{z=1}^n \tau_z \delta_z^3)^{1/3}, (\sum_{z=1}^n \tau_z \sqrt[3]{\gamma_z})^{1/3}] \dots \dots \dots (3)$

Definition

Let $R_z=(\delta_{R_z}, \gamma_{R_z})$ ($z=1$ to n) be the Cubic Root Fuzzy Set and $\tau = (\tau_1, \tau_2, \dots, \tau_n)^T$ be the weight vector of R_z with $\sum_{z=1}^n \tau_z = 1$. Then a Cubic Root Fuzzy Weighted Power Geometric (CRFWPG) operator is a function CRFWPG: $R^n \rightarrow R$, where
 CRFWPG $(R_1, R_2, R_3, \dots, R_n) = [(1 - \prod_{z=1}^n (1 - \delta_z^3)^{\tau_z})^{1/3}, (1 - \prod_{z=1}^n (1 - \sqrt[3]{\gamma_z})^{\tau_z})^{1/3}] \dots \dots \dots (4)$

Example

Let $R_1=(0.7,0.3)$, $R_2=(0.4,0.6)$, $R_3=(0.2,0.8)$ be three CRFS and assume that $\tau=(0.5, 0.2,0.7)^T$ is weight vector of R_z ($z=1$ to n), then

- (1) CRFWA $(R_1, R_2, R_3, \dots, R_n) = [\sum_{z=1}^n \tau_z \delta_z, \sum_{z=1}^n \tau_z \gamma_z]$
 $= (0.7 \times 0.5 + 0.4 \times 0.2 + 0.2 \times 0.7), (0.3 \times 0.5 + 0.6 \times 0.2 + 0.8 \times 0.7) = (0.57, 0.83)$
- (2) CRFWG $(R_1, R_2, R_3, \dots, R_n) = [\prod_{z=1}^n \delta_z^{\tau_z}, \prod_{z=1}^n \gamma_z^{\tau_z}]$
 $= (0.7^{0.5} \times 0.4^{0.2} \times 0.2^{0.7}), (0.3^{0.5} \times 0.6^{0.2} \times 0.8^{0.7})$
 $= (0.225, 0.423)$
- (3) CRFWPA $(R_1, R_2, R_3, \dots, R_n) = [(\sum_{z=1}^n \tau_z \delta_z^3)^{1/3}, (\sum_{z=1}^n \tau_z \sqrt[3]{\gamma_z})^{1/3}]$
 $= (0.5 \times 0.7^3 + 0.2 \times 0.4^3 + 0.7 \times 0.2^3)^{1/3}, (0.5 \times \sqrt[3]{0.3} + 0.2 \times \sqrt[3]{0.6} + 0.7 \times \sqrt[3]{0.8})^{1/3} = (0.063, 0.351)$
- (4) CRFWPA $(R_1, R_2, R_3, \dots, R_n) = [(\sum_{z=1}^n \tau_z \delta_z^3)^{1/3}, (\sum_{z=1}^n \tau_z \sqrt[3]{\gamma_z})^{1/3}]$
 $= ((1 - (1 - 0.7^3)^{0.5} \times (1 - (1 - 0.4^3)^{0.2} \times (1 - (1 - 0.2^3)^{0.7}))^{1/3},$
 $((1 - (1 - \sqrt[3]{0.3})^{0.5} \times (1 - (1 - \sqrt[3]{0.6})^{0.2} \times (1 - (1 - \sqrt[3]{0.8})^{0.7}))^{1/3}$
 $= (0.062, 0.287)$

Theorem

Let $R_z=(\delta_{R_z}, \gamma_{R_z})$ ($z=1$ to n) be the Cubic Root Fuzzy Set and $\tau = (\tau_1, \tau_2, \dots, \tau_n)^T$ be the weight vector of R_z with $\tau_z > 0$ and $\sum_{z=1}^n \tau_z = 1$. Then a CRFWPA($R_1, R_2, R_3, \dots, R_n$) is an CRFS.

Proof

For any CRFS $R_z=(\delta_{R_z}, \gamma_{R_z})$, we have $0 \leq \delta_{R_z}^3 \leq 1, 0 \leq \sqrt[3]{\gamma_{R_z}} \leq 1$
 $0 \leq \delta_{R_z}^3 + \sqrt[3]{\gamma_{R_z}} \leq 1$

Then, we given that

$$0 \leq \tau_1 \delta_{R_1}^3 + \tau_1 \sqrt[3]{\gamma_{R_1}} \leq \tau_1$$

$$0 \leq \tau_2 \delta_{R_2}^3 + \tau_2 \sqrt[3]{\gamma_{R_2}} \leq \tau_2$$

.....





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$$0 \leq \tau_n \delta_{R_n}^3 + \tau_n \sqrt[3]{\gamma_{R_n}} \leq \tau_n$$

And so , $0 \leq (\tau_1 \delta_{R_1}^3 + \tau_1 \sqrt[3]{\gamma_{R_1}}) + (\tau_2 \delta_{R_2}^3 + \tau_2 \sqrt[3]{\gamma_{R_2}}) + \dots + (\tau_n \delta_{R_n}^3 + \tau_n \sqrt[3]{\gamma_{R_n}}) \leq (\tau_1 + \tau_2, \dots, \tau_n)$

$$0 \leq \sum_{z=1}^n \tau_z \delta_{R_z}^3 + \sum_{z=1}^n \tau_z \sqrt[3]{\gamma_{R_z}} \leq \sum_{z=1}^n \tau_z = 1$$

Therefore $0 \leq ((\sum_{z=1}^n \tau_z \delta_{R_z}^3)^{1/3})^3 + ((\sum_{z=1}^n \tau_z \sqrt[3]{\gamma_{R_z}})^{1/3})^3$
 $= \sum_{z=1}^n \tau_z \delta_{R_z}^3 + \sum_{z=1}^n \tau_z \sqrt[3]{\gamma_{R_z}} \leq 1$

It is obvious that,

$$0 \leq (\sum_{z=1}^n \tau_z \delta_{R_z}^3)^{1/3} \leq 1, \quad 0 \leq (\sum_{z=1}^n \tau_z \sqrt[3]{\gamma_{R_z}})^{1/3} \leq 1$$

Then CRFWPA $(R_1, R_2, R_3, \dots, R_n)$ is an CRFS.

Theorem

Let $R_z = (\delta_{R_z}, \gamma_{R_z})$ ($z=1$ to n) and $R = (\delta_R, \gamma_R)$ be the Cubic Root Fuzzy Sets and $\tau = (\tau_1, \tau_2, \dots, \tau_n)^T$ be the weight vector of R_z with $\sum_{z=1}^n \tau_z = 1$. Then a $CRFWPA(R_1 \oplus R, R_2 \oplus R, \dots, R_n \oplus R) \geq CRFWPA(R_1 \otimes R, R_2 \otimes R, \dots, R_n \otimes R)$.

Proof

For any $R_z = (\delta_{R_z}, \gamma_{R_z})$ ($z=1$ to n) and $R = (\delta_R, \gamma_R)$, we have,

$$\delta_{R_z}^3 + \delta_R^3 - \delta_{R_z}^3 \delta_R^3 \geq 2\delta_{R_z}^3 \delta_R^3 - \delta_{R_z}^3 \delta_R^3 - \delta_{R_z}^3 \delta_R^3$$

$$\sqrt[3]{\gamma_{R_z}} + \sqrt[3]{\gamma_R} - \sqrt[3]{\gamma_{R_z}} \sqrt[3]{\gamma_R} \geq 2\sqrt[3]{\gamma_{R_z}} \sqrt[3]{\gamma_R} - \sqrt[3]{\gamma_{R_z}} \sqrt[3]{\gamma_R} = \sqrt[3]{\gamma_{R_z}} \sqrt[3]{\gamma_R}$$

That is $\sum_{z=1}^n \tau_z (\delta_{R_z}^3 + \delta_R^3 - \delta_{R_z}^3 \delta_R^3) \geq \sum_{z=1}^n \tau_z \delta_{R_z}^3 \delta_R^3$

$$\sum_{z=1}^n \tau_z (\delta_{R_z}^3 + \delta_R^3 - \delta_{R_z}^3 \delta_R^3)^{1/3} \geq (\sum_{z=1}^n \tau_z \delta_{R_z}^3 \delta_R^3)^{1/3}$$

$$\sum_{z=1}^n \tau_z (\sqrt[3]{\gamma_{R_z}} + \sqrt[3]{\gamma_R} - \sqrt[3]{\gamma_{R_z}} \sqrt[3]{\gamma_R}) \geq \sum_{z=1}^n \tau_z \sqrt[3]{\gamma_{R_z}} \sqrt[3]{\gamma_R}$$

We have $\sum_{z=1}^n \tau_z (\sqrt[3]{\gamma_{R_z}} + \sqrt[3]{\gamma_R} - \sqrt[3]{\gamma_{R_z}} \sqrt[3]{\gamma_R})^{1/3} \geq (\sum_{z=1}^n \tau_z \sqrt[3]{\gamma_{R_z}} \sqrt[3]{\gamma_R})^{1/3}$

$CRFWPA(R_1 \oplus R, R_2 \oplus R, \dots, R_n \oplus R) = \sum_{z=1}^n \tau_z (\delta_{R_z}^3 + \delta_R^3 - \delta_{R_z}^3 \delta_R^3)^{1/3},$

$$(\sum_{z=1}^n \tau_z \sqrt[3]{\gamma_{R_z}} \sqrt[3]{\gamma_R})^{1/3}$$

$CRFWPA(R_1 \otimes R, R_2 \otimes R, \dots, R_n \otimes R) = (\sum_{z=1}^n \tau_z \delta_{R_z}^3 \delta_R^3)^{1/3},$

$$\sum_{z=1}^n \tau_z (\sqrt[3]{\gamma_{R_z}} + \sqrt[3]{\gamma_R} - \sqrt[3]{\gamma_{R_z}} \sqrt[3]{\gamma_R})^{1/3}$$

Hence $CRFWPA(R_1 \oplus R, R_2 \oplus R, \dots, R_n \oplus R) \geq CRFWPA(R_1 \otimes R, R_2 \otimes R, \dots, R_n \otimes R)$

Theorem

Let $R_z = (\delta_{R_z}, \gamma_{R_z})$ ($z=1$ to n) and $R = (\delta_R, \gamma_R)$ be the Cubic Root Fuzzy Sets and $\tau = (\tau_1, \tau_2, \dots, \tau_n)^T$ be the weight vector of R_z with $\sum_{z=1}^n \tau_z = 1$. Then a $CRFWPA(R_1 \oplus R, R_2 \oplus R, \dots, R_n \oplus R) \geq CRFWPA(R_1, R_2, \dots, R_n) \otimes R$

Proof

Let $R_z = (\delta_{R_z}, \gamma_{R_z})$ ($z=1$ to n) and $R = (\delta_R, \gamma_R)$ be the Cubic Root Fuzzy Sets,

We have

$$[\sum_{z=1}^n \tau_z (\delta_{R_z}^3 + \delta_R^3 - \delta_{R_z}^3 \delta_R^3)]^{1/3} \geq [\sum_{z=1}^n \tau_z \delta_{R_z}^3 \delta_R^3]^{1/3} = \sum_{z=1}^n \tau_z \delta_{R_z}^3]^{1/3} \delta_R$$

$$\sum_{z=1}^n \tau_z (\sqrt[3]{\gamma_{R_z}} + \sqrt[3]{\gamma_R} - \sqrt[3]{\gamma_{R_z}} \sqrt[3]{\gamma_R})^{1/3} \geq (\sum_{z=1}^n \tau_z \sqrt[3]{\gamma_{R_z}} \sqrt[3]{\gamma_R})^{1/3} = (\sum_{z=1}^n \tau_z \sqrt[3]{\gamma_{R_z}})^{1/3} \sqrt[3]{\gamma_R}$$

We have,

$CRFWPA(R_1 \oplus R, R_2 \oplus R, \dots, R_n \oplus R) = [\sum_{z=1}^n \tau_z (\delta_{R_z}^3 + \delta_R^3 - \delta_{R_z}^3 \delta_R^3)]^{1/3}, \quad (\sum_{z=1}^n \tau_z \sqrt[3]{\gamma_{R_z}} \sqrt[3]{\gamma_R})^{1/3}$

$CRFWPA(R_1, R_2, \dots, R_n) \otimes R = [(\sum_{z=1}^n \tau_z \delta_{R_z}^3)^{1/3}, (\sum_{z=1}^n \tau_z \sqrt[3]{\gamma_{R_z}})^{1/3}] \otimes (\delta_R, \gamma_R)$

$$= [(\sum_{z=1}^n \tau_z \delta_{R_z}^3)^{1/3} \delta_R, (\sum_{z=1}^n \tau_z (\sqrt[3]{\gamma_{R_z}} + \sqrt[3]{\gamma_R})^{1/3}]$$

$$- \sum_{z=1}^n \tau_z \sqrt[3]{\gamma_{R_z}} \sqrt[3]{\gamma_R}]^{1/3}$$

It follow that

$CRFWPA(R_1 \oplus R, R_2 \oplus R, \dots, R_n \oplus R) \geq CRFWPA(R_1, R_2, \dots, R_n) \otimes R$





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Theorem: (Boundedness)

Suppose that $\delta_R^* = \min_{1 \leq z \leq n} \{\delta_{R_z}\}$, $\delta_R^\epsilon = \max_{1 \leq z \leq n} \{\delta_{R_z}\}$, $\gamma_R^* = \min_{1 \leq z \leq n} \{\gamma_{R_z}\}$, $\gamma_R^\epsilon = \max_{1 \leq z \leq n} \{\gamma_{R_z}\}$, then $(\delta_R^*, \gamma_R^\epsilon) \leq CRFWPA(R_1, R_2, \dots, R_n) \leq (\delta_R^\epsilon, \gamma_R^*)$.

Proof:

For any $R_z = (\delta_{R_z}, \gamma_{R_z})$ ($z = 1$ to n),

We have $\delta_R^* \leq \delta_{R_z} \leq \delta_R^\epsilon$ and $\gamma_R^\epsilon \leq \gamma_{R_z} \leq \gamma_R^*$

The inequities for MD value are

$$\delta_R^* = (\sum_{z=1}^n \tau_z \delta_{R_z}^3)^{1/3} \leq (\sum_{z=1}^n \tau_z \delta_{R_z}^3)^{1/3} \leq (\sum_{z=1}^n \tau_z \delta_{R_z}^3)^{1/3} = \delta_R^\epsilon$$

Similarly for NMD value are

$$\gamma_R^* = (\sum_{z=1}^n \tau_z \sqrt[3]{\gamma_{R_z}^*})^3 \leq (\sum_{z=1}^n \tau_z \sqrt[3]{\gamma_{R_z}})^3 \leq (\sum_{z=1}^n \tau_z \sqrt[3]{\gamma_{R_z}})^3 = \gamma_R^\epsilon$$

Hence $(\delta_R^*, \gamma_R^\epsilon) \leq CRFWPA(R_1, R_2, \dots, R_n) \leq (\delta_R^\epsilon, \gamma_R^*)$.

Theorem: (Monotonicity)

Let $R_z = (\delta_{R_z}, \gamma_{R_z})$ and $M_z = (\delta_{M_z}, \gamma_{M_z})$ ($z = 1$ to n) be the two CRFS If $\delta_{R_z} \leq \delta_{M_z}$

and $\gamma_{R_z} \leq \gamma_{M_z}$ then ,

$$CRFWPA(R_1, R_2, \dots, R_n) \leq CRFWPA(M_1, M_2, \dots, M_n)$$

Proof:

For all z , we have,

$$\delta_{R_z} \leq \delta_{M_z} \text{ and } \gamma_{R_z} \leq \gamma_{M_z} \text{ then } (\sum_{z=1}^n \tau_z \delta_{R_z}^3)^{1/3} \leq (\sum_{z=1}^n \tau_z \delta_{M_z}^3)^{1/3} \text{ and } (\sum_{z=1}^n \tau_z \sqrt[3]{\gamma_{R_z}})^3 \leq (\sum_{z=1}^n \tau_z \sqrt[3]{\gamma_{M_z}})^3$$

$$\begin{aligned} \therefore CRFWPA(R_1, R_2, \dots, R_n) &\leq [(\sum_{z=1}^n \tau_z \delta_{R_z}^3)^{1/3}, (\sum_{z=1}^n \tau_z \sqrt[3]{\gamma_{R_z}})^3] \\ &\leq [(\sum_{z=1}^n \tau_z \delta_{M_z}^3)^{1/3}, (\sum_{z=1}^n \tau_z \sqrt[3]{\gamma_{M_z}})^3] \\ &= CRFWPA(M_1, M_2, \dots, M_n) \end{aligned}$$

Hence $CRFWPA(R_1, R_2, \dots, R_n) \leq CRFWPA(M_1, M_2, \dots, M_n)$

Theorem: (Idempotency)

Let $R_z = (\delta_{R_z}, \gamma_{R_z})$ ($z = 1$ to n) be the Cubic Root Fuzzy Sets such that $R_z = R = (\delta_R, \gamma_R)$ and $\tau = (\tau_1, \tau_2, \dots, \tau_n)^T$ be the weight vector of R_z with Then $CRFWPA (R_1, R_2, R_3, \dots, R_n) = R$

Proof:

Since $R_z = R = (\delta_R, \gamma_R)$ ($z = 1$ to n) then

$$\begin{aligned} CRFWPA (R_1, R_2, R_3, \dots, R_n) &= (\sum_{z=1}^n \tau_z \delta_{R_z}^3)^{1/3}, (\sum_{z=1}^n \tau_z \sqrt[3]{\gamma_{R_z}})^3 \\ &= (\sum_{z=1}^n \tau_z \delta_R^3)^{1/3}, (\sum_{z=1}^n \tau_z \sqrt[3]{\gamma_R})^3 \\ &= (\delta_R, \gamma_R) \\ &= R \end{aligned}$$

Hence $CRFWPA (R_1, R_2, R_3, \dots, R_n) = R$

MCDM Problems using Aggregation Operators in Cubic Root Fuzzy Set

Algorithm:

Step:1

Consider $M_1, M_2, M_3, \dots, M_n$ be alternatives and $V_1, V_2, V_3, \dots, V_n$ be the parameters. Suppose that the Cubic root fuzzy sets $R_k = (\delta_k, \gamma_k)$, ($k = 1$ to n) where δ_k represent the MD of the alternative M_k ($k = 1$ to n) for the parameters V_i ($k = 1$ to n). Similarly, γ_k represent the NMD of the alternative M_k ($k = 1$ to n) for the parameters V_i ($k = 1$ to n).

Step:2

Cubic root fuzzy set are used to assign weight τ_k ($k = 1$ to n) to different parameter for a set of group.

Step:3

Calculate the CRFS values using the Aggregation Operators (equation (1),(2), (3), (4)).

Step:4





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Calculate the Score values using the formula (equation (A))

Step:5

Determine the alternative is smaller . As a output, the rank the alternative in descending order

Numerical Example

Assume that the Institution wants to fill a position of faculty there are four candidates can be taken the set of alternatives (M₁, M₂, M₃,M₄) . Consider a set of parameters (V₁, V₂, V₃,V₄) the parameters stands for “Communication” , “Experience” , “Good speaking” and “Computer knowledge” respectively.

STEP:1

Construct that the alternatives corresponding to each parameters is given in the form of Cubic Root Fuzzy Set

	V ₁	V ₂	V ₃	V ₄
M ₁	[0.33,0.67]	[0.25,0.73]	[0.94,0.12]	[0.24,0.87]
M ₂	[0.22,0.42]	[0.17,0.82]	[0.65,0.74]	[0.33,0.29]
M ₃	[0.34,0.86]	[0.48,0.64]	[0.47,0.23]	[0.45,0.51]
M ₄	[0.53,0.46]	[0.41,0.27]	[0.23,0.18]	[0.27,0.13]

STEP:2

Suppose that we take the weight τ_k (k = 1, 2, 3) in the form of Cubic Root fuzzy set with τ_z > 0 and Σ_{z=1}ⁿ τ_z = 1, weight τ₁=0.2, τ₂=0.4 , τ₃=0.6 and τ₄=0.5.

STEP:3

Calculate the CRFS values using the Aggregation Operators (equation (1),(2), (3), (4)), as shows in the table.

	M ₁	M ₂	M ₃	M ₄
CRFWA	[0.85,0.93]	[0.66,1.00]	[0.76,0.82]	[0.54,0.37]
CRFWG	[0.21,0.21]	[0.16,0.34]	[0.25,0.23]	[0.13,0.06]
CRFWPA	[0.17,0.39]	[0.06,0.42]	[0.05,0.38]	[0.02,0.31]
CRFWPG	[0.05,0.08]	[0.02,0.02]	[0.01,0.09]	[0.03,0.09]

STEP:4

Determine the Score values using the formula (equation (A)) , as shows in the table

	M ₁	M ₂	M ₃	M ₄
CRFWA	[-0.451]	[-0.703]	[-0.454]	[-0.450]
CRFWG	[-0.450]	[-0.590]	[-0.472]	[-0.240]
CRFWPA	[-0.621]	[-0.651]	[-0.628]	[-0.559]
CRFWPG	[-0.039]	[-0.094]	[-0.044]	[-0.029]

Step:5

The alternative can be calculate based on their smaller distance of above table are generated.

- CRFWA M₄>M₁>M₃>M₂
- CRFWG M₄>M₁>M₃>M₂
- CRFWPA M₄>M₁>M₃>M₂
- CRFWPG M₄>M₁>M₃>M₂

Along these results we findout the M₄ is the best candidate when compared with other candidates.





CONCLUSION

In this study, a set operators such as union, intersection and Cubic Root Fuzzy Weighted Average operator(CRFWA), Cubic Root Fuzzy Weighted Geometric operator(CRFWG), Cubic Root Fuzzy Weighted Power Average operator(CRFWPA), Cubic Root Fuzzy Weighted Power Geometric operator(CRFWPG), the classes of CR fuzzy set have been studied and discussed with proved their fundamental results. A MCDM approach is take to handle the decision making using CR fuzzy set operators and easily to evaluated the relevance outputs. In future we will use to cubic root fuzzy set in different area to verify the presented technique.

REFERENCES

1. Atanassov K.T, "Intuitionistic Fuzzy Sets".Fuzzy sets and Systems, 20(1986), pp.87-96.
2. Khan.F, Abdullah.s, Mahmood.T, Shakeel.M and Rahim.M,"Pythagorean Cubic Fuzzy Aggregation Information Based on Confidence Levels and its Application to Multi-Criteria Decision Making Process". Journal of Intelligent and Fuzzy systems, (2019 b), 36(6),pp.5669- 5683.
3. Muhammad.S, Muhammad Haris.S, Rimsha.S, Salvatore.S Umar.I and Ferdinando D.M, "A Theoretical Development of Cubic Pythagorean Fuzzy Soft Set with its Application in Multi- Attribute decision Making".Symmetry 2022, 14, 2639.
4. Balamurugan.K, Nagarajan.Dr.R, "Applications of Cubic Root Fuzzy Sets in Decision Making Approach". European Journal of Molecular and Clinical Medicine , ISSN 2515-8260, Vol 10, 2023.
5. Khan.F, Khan.M.S.A., Shahzad.M and Abdullah.S, "Pythagorean Cubic Fuzzy Aggregation Operators and their Application to Multi-Criteria Decision Making Process". Journal of Intelligent and Fuzzy systems, (2019 a), 36(1),pp.595-607.
6. Chinnadurai.V, Thayalan.S, Bobin.A, "Multi-Criteria Decision Making in Complex Fermatean Fuzzy Environment". J.Math.Comput. Sci. 11(2021), No.6, pp.7209-7227.
7. Paul Augustine Ejegwa, "Pythagorean Fuzzy set and its Application in Career Placements Based on Academic Performance Using Max-Min-Max Composition". Complex Intelligent systems (2019):pp.165-175.
8. Chinnadurai.V, Thayalan.S, Bobin.A, "Multi-Criteria Decision Making Process Using Complex Cubic Interval Valued Intuitionistic Fuzzy Set". Journal of Physics Conference Series 1850(2021), 012094.
9. Rodrigo barraza, Juanm Sepulveda and Ivan derpich, "Application of Fermatean Fuzzy Matric in Co-design of Urban Projects". Procedia Computer Science 199 (2022),pp.463- 470.
10. Anjan Mukherjee, Sadhan Sarkar and Somen Debnath, "Application of Intuitionistic Fuzzy Soft Set in Decision Making Based on real life problems",Communication in Mathematical Modeling and Application, CMMA 1. No.3,pp.16-21(2016).
11. Palanikumar.M, Arulmozhi.K, Aiyared Iampan, "Novel Possibility Pythagorean Cubic Fuzzy Soft Sets and their Application".InternationalJournal of Innovative Computing Information and Control, vol 19, No.2 (2023)
12. Zadeh L.A., "Fuzzy Sets ". Inf. Control, 8,pp.338-353.
13. Liu.D, Liu.Y and wang.L ,"Distance Measure for Fermatean Fuzzy linguistic Term Sets Based on Linguistic Scale Function:An Illustration of the TODIM and TOPSIS Methods". Intell syst., vol.wiley, No.1,DOI:10.1002/int.22162, pp.1-28,2019.
14. Yagar.R.R., Abbasov.A.M, "Pythagorean Membership Grades, Complex Numbers and Decising Making". Int. Jouranl Intell., Syst., pp.436-452, 28(2013).
15. Salih Y.A., Inrajo H.Z., "Cubic Root fuzzy sets and their Applications". J.Math Computer Sci.,pp 171-181,28 (2023).
16. Hariwan Z.Ibrahim, Tareq M. Al-Shami and Abdelwaheb Mhemdi ," Applications of n^{th} power Root Fuzzy sets in Multicriteria Decision Making", Hindawi Journal of Mathematics Vol (2023), pp 14.





Application of Queuing Theory for the Normal Petrol Station and Automated Petrol Bulk

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ABSTRACT

The emergence of queues is a common phenomenon that arises when the capacity to provide a service lags behind the demand for it. Although it is not always possible to predict with absolute certainty when customers will come and how long it will take to serve them, it is essential to be prepared, decisions about the extent of service provision need to be made regularly across various industries. This paper presents the findings of a study conducted on five petrol stations in Kanyakumari, Mussari, KaruMavilai, Mannanvilai, Katrukkadi and Alanchidistrict. The five petrol stations average customer arrival rates per hour were determined to be 95.4, 97.4, 98.5, 99.6, and 177.8 accordingly, while the average customer exit rate.

Keywords: petrol stations, arrival, departure.





INTRODUCTION

According to the First In First Out (FIFO) concept, the oldest entry in a queue is handled or eliminated first. The absence of random access to elements, capacity restrictions, and memory overhead are some of these queue drawbacks. Despite these shortcomings, queues are nevertheless a popular data management technology with a wide range of applications. These days, the abundance of cars has also led to a longer line at the gas station. In this research, we proposed automated petroleum bulk, conducted a thorough case study, and compared automated and conventional petroleum bulk.

MATERIALS AND METHODS

The Queueing System

Information on the flow of traffic to and from five different petrol stations. To illustrate, consider a petrol station's customer flow: as one client enters the waiting area, another leaves. This is known as a "birth-death" process, with "birth" referring to the entrance of a new customer and "death" referring to the departure of an existing customer. The lines at gas stations are distributed according to a multi-server arrangement, where customers follow a Poisson process with unlimited supply, and are represented by the notation (M/M/s):(FCFS). A first-come, first-served (FCFS) queueing system controls the flow of customers in and out of a service, where "M" represents the arrival process, "s" represents the number of servers. Since client arrivals are supposed to follow a Poisson distribution model with an arrival rate of λ per unit time, these queueing systems include numerous queues of identical servers operating in parallel. Customers are supposed to be served by any available server in a first-come, first-served fashion, and service times are expected to follow an exponential distribution with a rate of μ per unit time, on average. Little's laws, which state that the long-run average number of customers in a stationary system is equal to the long-run average effective arrival rate multiplied by the average duration a customer spends in the system, are used to establish the queue characteristics. In order for the system to perform optimally, the utilisation factor, which measures how much of the available system capacity is being utilised to handle incoming traffic, must be less than one. Vehicle arrival and departure times were recorded at five petrol stations in the Kanyakumari district: Alanchi (two servers and a FIFO queueing system), Karumavilai (three servers and a FIFO queueing system), Katrukadai (four servers and a FIFO queueing system) and Musari (eight servers and a FIFO queueing system). These petrol stations with a first-in-first-out (FIFO) queueing mechanism also contributed data. Table 1 displays data gathered from five petrol stations.

Little's Laws

The following relations between L_s , L_q , W_s and W_q are derived by using Little's laws.

Where

L_s = estimated number of clients in the system

L_q = estimate of customers in queue

W_s = Expected waiting time in system

W_q = Waiting time in queue

λ = Average rate of customer access to the system = Average service rate. Generally:

where λ is the average access rate, μ is the average service rate and

S is the number of servers.





$$L_s = \lambda W_s$$

$$L_q = \lambda W_q$$

$$W_s = W_q + \frac{1}{\mu}$$

$$\rho = \frac{\lambda}{\mu}$$

More generally,

$$\rho = \frac{\lambda}{\mu * S}$$

Typically, reduced utilization results in decreased customer waiting in queues, but it also implies greater system idleness, which could be perceived as inefficiency.

$$\rho = \frac{\lambda}{s\mu} = \frac{1.62}{(3)(1.26)} = 0.33$$

Two Server’s Case(M/M/2)

The Alanchi filling station employs a dual-service queue system in the form of an M/M/2 model, and the queue characteristics are determined as follows: Average customer arrival rate is $\lambda 2862/30 = 95.4/\text{hour}$ (94 customers per hour)

$L_s = \lambda W_s$ By equation

$$W_s = \frac{L_s}{\lambda}$$

$$W_s = \frac{L_s}{\lambda}$$

Typical wait time for the system

$$= 10.0 / 95.4$$

$$= 0.105 \text{ hr or } 6 \text{ min. } 18 \text{ sec. } L_q$$

$$= \lambda W_q$$

$$W_q = \frac{L_q}{\lambda}$$

Hence, the anticipated queue waiting time.

$$W_q = \frac{L_q}{\lambda}$$

$$= 8.0 / 95.4$$

$$= 0.084 \text{ hr. or } 5 \text{ min. } 2 \text{ sec.}$$

The time it takes for a customer to get service, $\mu = \text{system wait time minus queue wait time}$

$$\mu = 6 \text{ minutes. } 18 \text{ seconds.} - 5 \text{ minutes. } 2 \text{ seconds.} = 1 \text{ minute. } 16 \text{ seconds. (1.26min.)}$$

Factor of utilization

$$\rho = \frac{\lambda}{s\mu} \lambda = 95.4/\text{hour} = 1.59/\text{min} \text{ and } s = 2, \text{ while } \mu = 1.26 \text{ min}$$





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$$\rho = \frac{\lambda}{s\mu} = \frac{1.59}{(2)(1.26)} = 0.63$$

Three Server’s Case (M/M/3)

Karumavilai filling station employs a queuing system with three servers in the M/M/3 model. The queue parameters are specified as follows: The average customer arrival rate, denoted as λ , is calculated as 2922/30, equivalent to 97.4 per hour (97 customers per hour). Consequently, the focus lies on determining the expected waiting time within the system.

$$W_s = \frac{L_s}{\lambda}$$

$$= 10.0 / 97.4$$

$$= 0.103 \text{ hr} = 6.18 \text{ min.}$$

$$Lq = \lambda Wq$$

Hence, the anticipated queue waiting time.

$$W = \frac{Lq}{\lambda}$$

$$W_q = \frac{Lq}{\lambda}$$

$$= 8.0 / 97.4$$

$$= 0.082 \text{ hr.} = 4.92 \text{ min}$$

Expected service time, $\mu = 6.18 - 4.92 = 1.26$ minutes

Factor of utilization

$$\rho = \frac{\lambda}{s\mu}$$

$$\rho = \frac{\lambda}{s\mu} = \frac{1.62}{(3)(1.26)} = 0.33$$

Four Server’s Case(M/M/4)

The queue system at the Mananvillai Total Filling Station operates on a four-server queue model, characterized as an M/M/4 system with First-In-First-Out (FIFO) queuing discipline. The relevant queue parameters have been determined as follows: Normal client appearance rate λ 2955/30 = 98.5/hour (99 clients each hour) Anticipated holding up time in the framework

$$W_s = \frac{L_s}{\lambda}$$

$$= 10.0 / 98.5$$

$$= 0.102 \text{ hr} = 6.12 \text{ min.}$$

$$Lq = \lambda Wq$$

$$W_q = \frac{Lq}{\lambda}$$

Hence, the anticipated waiting duration in the line. $W_q = \frac{Lq}{\lambda}$

$$= 8.0 / 98.5$$

$$= 0.081 \text{ hr.} = 4.86 \text{ min}$$

Expected service time $\mu = 6.12 - 4.86 = 1.26$ minutes

Utilization factor $\rho = \frac{\lambda}{s\mu}$





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Five Server's Case (M/M/5)

The Katrukadai filling station employs a queue system consisting of five service servers, following the M/M/5 model with a FIFO (First-In-First-Out) approach. The parameters of the queue system have been determined as follows: Average arrival rate of customers, $\lambda = 2988/30 = 99.6$ /hour or 100 customers per hour Expected waiting time in the system

$$W_s = \frac{L_s}{\lambda}$$

$$= 10.0 / 99.6$$

$$= 0.10 \text{ hr} = 6 \text{ min.}$$

$$Lq = \lambda Wq$$

Hence, the anticipated waiting duration in the line.

$$W = \frac{L_q}{\lambda}$$

$$W_q = \frac{L_q}{\lambda}$$

$$= 8.0 / 99.6$$

$$= 0.082 \text{ hr.} = 4.8 \text{ min}$$

Anticipated duration of service, $6 - 4.8 = 1.2 \text{ min}$

Factor of utilization

$$\rho = \frac{\lambda}{s\mu}$$

$$= 0.28$$

Eight Server's Case (M/M/8)

The queue parameters at the NNPC Mega filling station are as follows: The queue model is an M/M/8 model with a FIFO (First-In, First-Out) discipline. Case of the Eighth Server Customers arrive at a pace of around 178 per hour on average $\lambda = 5334/30 = 177.8$ /hour). Duration of expected system delay

$$W_s = \frac{L_s}{\lambda}$$

$$= 10.0 / 177.8$$

$$= 0.56 \text{ hr} = 3.36 \text{ min.}$$

$$Lq = \lambda Wq$$

$$W_q = \frac{L_q}{\lambda}$$

Hence, the anticipated queue waiting time.

$$W_q = \frac{L_q}{\lambda}$$

$$= 8.0 / 177.8$$

$$= 0.045 \text{ hr.} = 2.7 \text{ min}$$

Anticipated service duration, $\mu = 3.36 - 2.7 = 0.66 \text{ min}$ Factor of utilization

$$\rho = \frac{\lambda}{s\mu}$$

$$= 0.56$$

DISCUSSION AND RESULTS

The calculated results for the average client arrival rate, the average queue wait time, the average service rate, and the average wait time inside the system are shown in Table 2. In addition, the utilisation factor was calculated for each petrol station, with the findings showing that for all stations, the factor was less than one. The findings also unveiled distinct patterns in customer influx into the system. Specifically, there were surges of customers during the early morning rush to offices, lunch breaks, the conclusion of the workday as people returned home, weekends,



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and times of fuel scarcity. Notably, Fridays and weekends exhibited unique queue situations at the gas stations, with motorists frequently forming extensive lines in anticipation of service. Furthermore, it was consistently observed that the appearance rate surpassed the assistance rate for all stations during the weekends. The findings indicate that, consistently, the rate at which customers arrived at filling stations exceeded the rate at which customers departed from them. This phenomenon accounts for the perpetual presence of queues at all the filling stations. This trend is evident when examining the arrival and service rates for both Alanchi petrol stations and Karumavillai petrol stations, which consistently show that the arrival rate exceeded the service rate. It highlights that customers entered the stations for service at a faster pace than they left after being served, leading to persistent queues at these stations. Notably, the Musari filling station, equipped with eight (8) service stations, displayed a virtually similar arrival rate and service rate of consumers. A similar pattern was seen at the five (5) service point Katrukadai petrol station.

CONCLUSION

In our increasingly congested and urbanized society, queueing systems have become more widespread. These queues can encompass various scenarios, such as data awaiting processing, equipment components in assembly lines, or individuals lining up at different types of business establishments. Queue theory serves as a vital tool for modeling numerous supply chain issues and is instrumental in analyzing situations where customers wait in line to receive service at manufacturing or service facilities. According to the results of the research, all of the petrol stations had utilisation factors lower than one (1), suggesting that the service providers were effectively meeting the needs of their clients. Usage factors were calculated to be 0.63 for the Alanchi filling station, 0.33 for the Karumavillai filling station, 0.33 for the Manavillai filling station, 0.28 for the Katrukadai filling station, and 0.56 for the Musari Mega filling station. Only one petrol station, the Musari Mega, was using all of its service stations to their maximum capacity. Therefore, petrol stations should make an effort to use all of their service points (pumps) at peak times to reduce wait times.

Case Study

We have done the case study in all these bulks it been calculated time per litres.

Automated Petrol Stations

The function of automation in the modern world is essential. The primary objective of this project is to create a system that employs radio frequency identification (RFID) technology to automatically deduct the amount of provided gasoline from a user's card, and then relay that transaction data and total to the owner via the Internet of Things (IoT). Offices, bus stops, train stations and gas stations are just a few of the many places we often meet liquid dispensing devices. Here, we introduce a state-of-the-art fuel station pump that accepts prepaid cards and using radio frequency identification technology. The primary goals of this project are to develop and deploy an RFID-based fuel delivery system and a prepaid card system for gas stations. It takes a lot of time and effort to manually run a fuel station at the moment. The high cost of opening a fuel station in a rural region makes it difficult to give excellent service to locals and visitors alike. In the modern era, virtually all gas stations are equipped with a control unit designed to manage various tasks such as controlling the electric pump, displaying information, measuring fuel flow, and shutting off the electric pump as needed. However, there is still a need for human intervention to handle cash collection and oversee the distribution of fuel at each individual petrol station. The objective of this project is to create a system that eliminates the need for human involvement, thereby negating the necessity for attendants to manually dispense fuel and monitor each gas station independently. In this innovative system, all drivers are issued smart cards, and all relevant information is transmitted to a central administrator via the Internet of Things (IoT). The project makes use of several different parts, such as a prepaid card, radio frequency modems, microcontroller, keyboard, screen, and solenoid valve. This automation system will significantly reduce the need for human labor and save valuable time. Customers can simply input the desired fuel quantity via the





keypad, and the system will handle the fuel dispensing process. The RFID-based automated petrol station aims to minimize human intervention and implement a self-guided mechanism using RFID technology to efficiently carry out tasks. These systems are known for their reliability and time-saving capabilities. The Internet of Things (IoT) is harnessed to monitor every aspect of the petrol station's operations remotely, including the ability to place orders for fuel from the industry. Microcontroller, Wi-Fi module, RFID tags, power supply, LCD display, solenoid valve, and RFID reader are among the essential parts used in this project. Oil and its derivatives are a precious and necessary part of the natural world.

PROPOSED SYSTEM

Our proposed solution involves a streamlined process where the customer inputs the desired fuel price through a keypad, initiating the automatic fueling of the vehicle. The system seamlessly detects the fuel level and ensures full automation. The concept of an RFID-based computerized petroleum siphon means to limit human mediation and lay out an independent system, employing RFID technology for consecutive task execution. These systems are known for their exceptional reliability and efficiency, significantly reducing the time required for fueling. We integrate IoT to monitor all activities within the petrol station, allowing remote management such as placing petroleum orders from the industry. Given the value and scarcity of petroleum products, our system plays a pivotal role in curbing fuel theft and wastage, preserving this precious natural resource.

DESIGN METHODOLOGY

The system operates in a sequential process, ensuring it examines each condition prior to initiating any thread or process. Initially, the system awaits the arrival of a user who will input their desired petrol quantity. Upon the user's input of a specific value, the system prompts them to swipe their license card, which also serves as their identification. Both audio and visual instructions are provided via LCD screen. There are now two probable outcomes: The gas pump will only release its contents if there is enough money on the user's card to cover the cost of the transaction. However, if the card does not contain the required funds, a transaction failure message is displayed on the screen. All transaction details are transmitted over the internet to the owner, and this entire cycle perpetually repeats.

ADVANTAGES

1. There will be a substantial reduction in human labor.
2. Minimal time consumption is involved.
3. Observing transactions in real-time.
4. The entire system will be fully automated.
5. There won't be any employees, thus eliminating employer expenses.
6. Efficient lane control will be ensured.
7. An alarm will sound in case of a security breach..

RESULT

In this process, the user initiates the operation by entering the desired amount and providing their smart card and biometric information. After the predetermined quantity is subtracted, the fuel nozzle will automatically relocate to a position where it may refuel the vehicle's tank with petrol or diesel. The user proceeds to insert the nozzle, which triggers the discharge of fuel. On the owner's side, when a transaction occurs, all pertinent data is transmitted via the Internet of Things (IoT) to the owner's application, resulting in the immediate update of the transaction list. This updated list includes details such as the quantity of dispensed petrol and the timestamp of the transaction. Furthermore, as the fuel level in the vehicle's tank approaches the minimum threshold, the owner receives





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notifications, enabling them to conveniently place an order for additional petrol.

FUTURE SCOPE

Should the government or major corporations show an interest in launching such an initiative, the entire network of gasoline stations can be interconnected, leading to the successful provision of 24/7 services. By integrating these systems, users would have the ability to locate the nearest petrol station and check their fuel availability. In the future, the inclusion of a biometric scanner and a password system could be considered, where vehicle numbers are cross-referenced with a database of stolen vehicles. A picture of the car and its location would be sent to the nearest police station if a match was established.

CONCLUSION

The RFID system provides the precise amount of fuel specified by the customer, reducing fuel wastage and minimizing the need for manual labor. In case a customer attempts to use an unauthorized card for swiping, the RFID system will decline the card, ensuring a high level of security. Hence, the system is highly secure. To achieve optimal performance, it is essential to use high-quality RFID readers and tags, and for seamless IoT connectivity, a strong internet connection is imperative. From this we can reduced the timings and the queue. As in the previous chapter we have designed the case study time per litres, but here the timings is same due to the automated system and is the self service. By comparing these two petrol bulks Automated filling station can be used in busybulks.By using this we can gain customer due to the less waiting time. If government approves in busy filling station better we can use Automated filling station so the flow of customer will be increase.

REFERENCES

1. L.Abolnikov, J.E. Dshalalow, A.M.Dukhovny. On Some Queue Length Controlled Stochastic Processes. *Journal of Applied Mathematics and Stochastic Analysis*. 1990;3(4): 227-244,
2. I.J.B.F Adan, O.J.Boxma, J.A.C Resing. *Queueing models with multiple waiting lines*. Department of Mathematics and Computer Science. Eindhoven University of Technology, Netherlands, 2000.
3. J. Banks, J.S. Carson, B.L.Nelson, D.M.Nicol. *Discrete-Event System Simulation*. 3rd edition. Prentice Hall. Upper Saddle River. New Jersey, 2001.
4. N.T. Bailey, A Continuous Time Treatment of Simple Queue Using Generating Functions. *Journal of the Royal Statistical Society*, 1954;16:288-291.
5. J.W. Cohen. Some Aspects of Queueing Theory. *Journal of Probability and Mathematical Statistics*. 2008; 28 (2):55-67.
6. R. Deb, K. Rajat. Optimal control of bulk queues with compound Poisson arrivals and batch service. *Journal of Operations Research*, 1984; 21(4):227-245.
7. O. O. Edward. A research using remote monitoring technology for pump output monitoring in a distributed fuel station in Nigeria. *International journal of Advances in Engineering and Technology*, 2014; 6:2408-2415.
8. Z.Cekerevac, S.Matic, D.Duric, D.Celebic. Fuel is pensor control system as the technical solution for preventing non-authorized fuelling. eleventh International Scientific Conference devoted to Crises Situations Solution in Specific Environment. Zilina, 2006.
9. M. A. Kulkarni , S. S. Taware. Embedded security system using RFID & GSM. *International Journal of Computer Technology and Electronics Engineering (IJCTEE)*, 2011;2(1):164-168.
10. M. Patil Aishwarya , J. Phukesayali, B.Tapasnehal. College access and student attend ancesing 'RFID' technology.
11. H.Jadhav, K.D.Pawar, P.M.Pathare, P.Patil, R.S.Pawar. Multi-Automized fuel pump with user security. *International Journal of Scientific and Technology Research*, 2014;3(5)





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12. D. B. A. Johnson, P. Jaska, J. Nalla, N. V. K. Reddy , R. Tadisina. Improved customer service using RFID technology.
13. J. M. Read, J. R. E. Bridgen, D. A. T. Cummings, A. Ho, C. P. Jewell. Novel coronavirus 2019-nCoV: early estimation of epidemiological parameters and epidemic predictions. MedRxiv, 2020.
14. T. Sardar, I. Ghosh, X. Rodó, J. Chattopadhyay. A realistic two-strain model for MERSCoV infection uncovers the high risk for epidemic propagation. PLoS Negl. Trop. Dis. 14(2):e0008065, 2020.
15. B. Tan, X. Wang, Q. Li, N. L. Bragazzi, S. Tang, Y. Xiao, J. Wu. Estimation of the transmission risk of the 2019-nCoV and its implication for public health interventions. J. Clin. Med., 2020; 9(2):462.
16. P. Thinley. Technical comments on the design and designation of biological corridors in Bhutan: global to national perspectives. J. Renew. Nat. Resour. Bhutan, 2010; 6:91–106.
17. G. T. Tilahun, H. T. Alemneh. Mathematical modelling and optimal control analysis of COVID-19 in Ethiopia. J. Interdiscip. Math., 2021; 1–20. <https://doi.org/10.1080/09720502.2021.1874086>
18. World Health Organization et al.: Coronavirus disease 2019. 2020. Available online at <https://www.who.int/emergencies/diseases/novel-coronavirus-2019> (accessed June 18, 2020), 2020.
19. World Health Organization et al.: Key messages and actions for COVID-19 prevention and control in schools, 2020.

Table 1: Frequency of Visits to and Efficiency of Service at Five gas stations

Period	Alanchi		karumavillai		Mananvillai		Katrukadai		Musari	
	λ	M	λ	μ	λ	μ	λ	M	λ	μ
8-9am	92	81	103	92	100	90	80	73	110	103
9– 10 am	94	88	100	90	93	87	90	83	103	98
10-11am	98	83	103	82	90	80	99	80	108	100
11–12pm	92	86	101	90	87	80	98	83	105	95
12-1pm	92	81	94	82	88	83	90	70	111	93
1-2pm	92	86	101	90	87	80	98	83	105	95
2-3pm	92	81	94	82	88	83	90	70	111	93
3-4pm	92	81	103	92	100	90	80	73	110	103
4-5pm	94	88	100	90	93	87	90	83	103	98
6-7pm	98	83	103	82	90	80	99	80	108	100
7-8pm	92	86	101	90	87	80	98	83	105	95
8-9 pm	92	81	94	82	88	83	90	70	111	93
10-11pm	92	86	101	90	87	80	98	83	105	95
11-12pm	92	81	94	82	88	83	90	70	111	93
12-1 am	92	86	101	90	87	80	98	83	105	95
1-2am	92	81	103	92	100	90	80	73	110	103
2-3am	94	88	100	90	93	87	90	83	103	98
2-4am	98	83	103	82	90	80	99	80	108	100
4-5am	92	86	101	90	87	80	98	83	105	95
5-6 am	92	81	94	82	88	83	90	70	111	93
6-7am	92	81	103	92	100	90	80	73	110	103
7-8am	94	88	100	90	93	87	90	83	103	98





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Table 2. Summary of the result

No of Servers	Average arrival/hr	Average departure/hr	L_s	L_q	W_s	W_q	μ	ρ
2	95.4	86.2	10	8	6.30	5.04	1.26	0.63
3	97.4	89	10	8	6.18	4.92	1.26	0.33
4	98.5	89.7	10	8	6.12	4.86	1.26	0.33
5	99.6	91.7	10	8	6.00	4.80	1.20	0.28
8	177.8	171.6	10	8	3.36	2.70	0.66	0.56

Table 3: Petrol Station in Alanchy

S.NO	LITRES	TIME
1	1	8.72sec
2	2	17.44sec
3	3	26.16sec
4	4	34.88sec
5	5	43.6sec
6	6	52.32sec
7	7	1min1sec
8	8	1min9sec
9	9	1min18sec
10	10	1min27sec

Table 4: Petrol Station in Karumavilai

S.NO	LITRES	TIME
1	1	9.24sec
2	2	18.48sec
3	3	27.72sec
4	4	36.96sec
5	5	46.2sec
6	6	55.44sec
7	7	1min4sec
8	8	1min13sec
9	9	1min23sec
10	10	1min32sec



**Murugananatha Prasad et al.,****Table 5: Petrol Station in Mannanvilai**

S.NO	LITRES	TIME
1	1	10.18sec
2	2	21.6sec
3	3	32.4sec
4	4	43.2sec
5	5	54sec
6	6	1min4sec
7	7	1min15sec
8	8	1min26sec
9	9	1min37sec
10	10	1min48sec

Table 6: Petrol Station in Kaddukadai

S.NO	LITRES	TIME
1	1	9.7sec
2	2	19.4sec
3	3	29.1sec
4	4	38.8sec
5	5	48.5sec
6	6	58.2sec
7	7	1min7sec
8	8	1min17sec
9	9	1min27sec
10	10	1min37sec

Table 7: Petrol Station in Musari

S.NO	LITRES	TIME
1	1	7.48sec
2	2	14.96sec
3	3	22.44sec
4	4	29.92sec
5	5	37.4sec
6	6	44.88sec
7	7	52.36sec
8	8	59.84sec
9	9	1min7sec
10	10	1min14sec





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Figure.1 Demonstrates the Methods used in the Conceived System





Formulation and Evaluation of Fast Dissolving Tablets Containing Methanolic Leaf Extract of *Psidium guajava* Linn. Evincing Anti Hyperglycemic Activity

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ABSTRACT

Psidium guajava Linn., a medicinal plant familiar with Ayurvedic medicine and found worldwide, has leaves rich in phytochemicals. These compounds have demonstrated various beneficial effects, including anticancer, antioxidant, anti-diarrhoea, antimicrobial, anti-obesity, lipid-lowering, hepatoprotective, and anti-hyperglycaemic properties. This research aimed to create fast-dissolving tablets using methanolic leaf extracts of *Psidium guajava*, which have demonstrated anti-hyperglycaemic activity by inhibiting enzymes for instance α -Amylase and α -glucosidase. The tests for identification and in vitro anti-hyperglycaemic activity of plant extract were positive. FTIR and DSC analyses confirmed the compatibility of the leaf extract and excipients. Fast-dissolving tablets were chosen as the formulation method to improve the bioactivity of the extract, given the typically low bioavailability of herbal formulations. The formulas were optimized using Design Expert 10.0 software and 3^2 factorial designs. This design aimed to study the effects of the independent variables Crospovidone (X1) and Micro Crystalline Cellulose (X2), in combination. Three responses - disintegration time (Y1), % drug release (Y2), and friability (Y3) - were evaluated in this design, and experimental trials were conducted for all nine formulations. All formulations underwent pre-compression and post-compression studies. The





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optimal formulation, C1, was identified by the model, with characteristics of 0.52 ± 0.010 seconds for friability, 93.8 ± 0.014 % for drug release, and 38 ± 1.0 seconds for disintegration time.

Keywords: *Psidium guajava* Linn., Fast dissolving Tablets, Anti-Hyperglycemic Activity, Crospovidone, Microcrystalline cellulose, Disintegration time.

INTRODUCTION

As the global occurrence with regard to type 2 diabetes (T2D) continues to increase, there is a growing demand for more tailored treatments to lessen complications and enhance the cost efficiency of current therapies. In 2021, over 61 million individuals in Europe were impacted by T2D, resulting in healthcare expenses of \$189 billion[1]. Diabetes mellitus have being a Byzantine and multifaceted cluster of disorders that disrupt the metabolic processing of carbohydrates, fats, and proteins [2]. This metabolic illness is defined by an inability to maintain glucose homeostasis and problems with protein, lipid, and carbohydrate digestion brought on by deficiencies in insulin action, secretion, or both[3]. The main threat factor for chronic illnesses including diabetes, cancer, heart disease, and neurological disorders is becoming older. These illnesses can impair sensory, motor, and cognitive skills, which can lower quality of life. They now disproportionately impact the older population. Managing various illnesses is the most medical problem facing the rise in number of senior individuals being treated[4]. According to the World Health Organization, apropos 3% of the total global population has diabetes and it's expected to increase by the year 2025[3]. The prevalence of diabetes is rising worldwide, impacting more than 10% of the population. In Finland, 10% of women and 15% of men, or 429,000 individuals out of 5.5 million total, were predicted to have diabetes in 2017. This number does not include those under 30. Diabetes is linked to significant morbidity and high death rates. If managed, persistent hyperglycaemia can damage several organs and result in severe consequences. This is especially true for patients with type 2 diabetes (T2D) who are older in demographics, since they have a larger comorbidity load [5]. Owing to the severe consequences of diabetes, a variety of options are available, including medications, dietary modifications and regimens, physical activity, and more[2]. The medical community continues to face difficulties in managing diabetes without any adverse effects. The pharmacokinetic characteristics, subsequent failure rates, and associated adverse effects of the medications limit their usage. Therefore, the hunt for a novel class of chemicals is crucial to resolving diabetic issues. The search for alternative drugs is ongoing [3]. Currently, a variety of medication classes are offered on the market, including thiazolidinedione, alpha-glucose inhibitors, and sulfonylureas.

However, research has indicated that starting sulfonylurea treatment for diabetes mellitus is interconnected with a higher risk of heart failure and other side effects. Since the body becomes resistant to insulin in mild to severe renal failure, metformin is currently the first-line recommended therapy for diabetes mellitus. It's critical to decide if alternative drugs should be prioritized above metformin and sulfonylureas[6]. Plants are currently the source of 25% of medications, demonstrating the effectiveness of plant-based therapy. Medicinal plants are increasingly sought after due to their wide availability and lower toxicity to humans, and their use continues to expand[7]. The production of natural products and medicines has recently garnered significant interest. The guava plant (*Psidium guajava*), often used in traditional medicine, is believed to contain active compounds that assist in the treatment and control of various health conditions[8]. *Psidium guajava* Linn. is a plant that has anti-hyperglycaemic characteristics. This is because the plant's leaves and fruits contain secondary metabolites such flavonoids and phenolic compounds.[9]*Psidium guajava* Linn., habitually referred to as Peru or guava, is comes under the family of Myrtaceae [2]. Guava trees are small, evergreen plants. The leaflets of the guava tree are between one and two inches in width and length. When wrinkled, the leaves have a pleasant perfume. They have a stiff, leathery feel and a dull green hue with prominent veins. Bioactive chemicals found in guava leaves have antibacterial qualities, control blood sugar levels, and may even help with weight reduction. Additionally, they comprises of essential oil that is rich in a variety of components, including fat, cellulose, chlorophyll, cineol, tannins, triterpenes, flavonoids, resin, and eugenol[8]. This can be discovered in Subhumid areas like South America, Indonesia, Bangladesh, India, and





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Pakistan. Many places have used different portions of the guava tree to cure ailments like diabetes, dyspepsia, diarrhoea, and other health issues [7]. *Psidium guajava* leaves, in particular, have been used to cure a number of illnesses, including dysentery, cough, diarrhoea, and stomach discomfort. The leaves have shown antibacterial, antispasmodic, myocardial depressant, cardioprotective, and hypoglycaemic properties. *Psidium guajava* leaves have the potential to block the α -amylase and α -glucosidase enzymes, which may help individuals with hyperglycaemia effectively regulate their blood sugar levels after meals [2]. The extract's phenolic chemicals and triterpenes may have altered glycogen metabolism, which in turn might have played a part in *Psidium guajava*'s anti-hyperglycaemic action[9]. Phenolic substances consisting of rutin, isoquercitrin, avicularin, quercitrin, kaempferol-3-arabofuranoside, quercetin, and kaempferol, as well as gallic acid, chlorogenic acid, epicatechin, and mono-3-hydroxyethyl-quercetinglucuronide[10]. *Psidium guajava* has a lethal dosage 50 (LD50) more than 5000 mg per kilogram of body weight[11]. Oral administration is often the handpicked route of administration because of its convenience, patient adherence, stability, and minimal space requirements for storage [12]. Even with considerable progress in pharmaceutical research and development, the oral method of administration, which encompasses tablets and capsules, continues to be the favoured approach due to its many advantages. These include patient adherence, ease of intake, and less discomfort compared to parenteral drug delivery systems[13]. Oral hypoglycaemic drugs available in the market may lead to liver dysfunction, weight increase, and gastrointestinal discomfort. Therefore, the development of novel, potent drugs is desperately needed for the prevention and management of diabetes mellitus[14]. By creating a dose form that is simple to give, advances in Novel pharmacological Delivery Systems (NDDS) seek to improve patient adherence while simultaneously enhancing the safeness and effectiveness of drugs molecules[15]. The term "Oro dispersible tablet" has been introduced by the European Pharmacopoeia to denote a tablet that, when placed in the mouth, quickly disintegrates before being swallowed, highlighting its growing importance[16]. A staggering 35 percent of the universal population has difficulty in consuming tablets or capsules, including children, the elderly, hospitalized patients, and people who suffer motion sickness, nausea, or vomiting[13]. To facilitate easier gulping, the solid Fast Dissolving Tablet (FDT) dosage form converts into a soft paste or liquid state, thereby mitigating the risk of choking[15].

Fast Dissolving Tablets (FDTs) that disintegrate rapidly result in an increased surface area and faster dissolution, leading to the release of a finely dispersed array of drug particles[16]. Fast Dissolving Tablets (FDTs) are described as "a solid dosage form that contains medicinal substances and disintegrates quickly, typically in a few seconds, when positioned on the tongue" by the Food and Drug Administration (FDA)[13]. The effortless and Celerity of production make compressed Fast Dissolving Tablets (FDTs) highly favoured. They require a sophisticated formulation design that uses effervescent excipients or super disintegrating agents to ensure a disintegration time of just a few seconds. FDTs offer more advantages compared to conventional compressed tablets. They are extremely convenient as they allow for consumption at any time without the need for water and avoid the ingestion of large tablets or capsules. Moreover, the dissolution within the mouth cavity might even allow for pre-gastric absorption, potentially reducing early metabolism or providing a faster onset of action. Considering the taste when the tablet dissolves in the mouth is vital for Fast Dissolving Tablets (FDTs). Furthermore, to strike a balance between the tablet's mechanical strength and the time it takes to disintegrate, FDTs are typically produced using more complex formulation methods[12]. Among various dosage forms, oral administration is used for 50-60% of all dose formulations^[16].so FDTs are widely accepted over other conventional oral formulations due to their advantages. The Foremost purpose of this study is to formulate a safe & effective anti-diabetic fast-dissolving tablet using herbal extract (i.e., *Psidium guajava* methanolic leaf extract) as API in FDTs and their In-Vitro drug release comparison study with marketed FDTs.

MATERIALS AND METHODS

Collection of plants

The *Psidium guajava* Linn. leaves. had been collected in November 2023 from the Chalapathi Institute of Pharmaceutical Sciences' medicinal garden at Lam, Guntur, Andhra Pradesh, India. Dr. P. Satyanarayana Raju, a



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taxonomist from Acharya Nagarjuna University's Department of Botany & Microbiology in Guntur, Andhra Pradesh, India, certified the plant.

Chemicals & instruments used

Methanol, potassium Dihydrogen ortho phosphate, Ammonium hydroxide solution, Ferric chloride solutions, Chloroform, Glacial Acetic acid, Sulfuric acid are obtained from Qualigens,thermo fisher scientific, Mumbai. Microcrystalline cellulose, Saccharin sodium, Lactose, Talc, Magnesium stearate, Rutin, Magnesium ribbon fragments obtained from Loba Chemie Pvt Ltd, Mumbai. Crospovidone obtained from Bangalore Fine chem, Bangalore. Mannitol obtained from Fisher Scientific, Mumbai. Test tubes and beakers of Borosil® Limited, Mumbai. Weighing balance of LABINDIA®, 1MLH Magnetic stirrer of REMI, Rotary Evaporator of LABINDIA®, Rotatory tablet punching machine-single punch(Cadmach Rotary punch), HPTLC of ACTRON), TLC plates, Dissolution test apparatus of DS-8000,LABINDIA®, DSC instrument of Q20 from TA Instruments), FTIR instrument of Bruker alpha-T), UV-VISIBLE spectrophotometer of UV 3092,LABINDIA®, friability Apparatus of SECOR INDIA.

Extraction process

Extraction of the plant material and identification of the active ingredients in the plant are steps in the first phytochemical screening process. Method of extraction- In this extraction process, we have used the maceration method of extraction by using a magnetic stirrer apparatus for continuous exposure of parched leaf powder with methanol. Materials for Extraction- Magnetic stirrer, Alcohol (Methanol-99.5%), Sheid dried coarse powder of leaves of Psidium guajava Linn. Methanolic Extract preparation-After being washed with tap water, the P. guajava leaves were allowed to air dry at room temperature. Then, an electric mixer/blender was used to grind them into a powder. Then, 180 g of this powder was steeped for 48 hours at room temperature, stirring now and then, in 2 Liters of methanol. After that, the blend was passed through a Whatman No. 1 filter. After that, the sift was concentrated at 65 °C in a rotary evaporator to provide a residue that was the methanol extract. This extract underwent further drying in a 40 °C oven[17]. The extraction process is shown in **Figure 1**.

Identification tests

Analysis of extract was carried out to determine whether the guava leaf extract contained any bioactive ingredients. To identify several active chemical compounds such carbohydrates, tannins, saponins, cardiac glycosides, steroids/triterpenoids, flavonoids, anthraquinones, and alkaloids, a qualitative chemical investigation was conducted on the primitive methanolic extract of P. guajava. Standard procedures were used to analyse the phytochemicals [18].

Melting point

The drug can be identified in this way by testing the melting point as per "THE INDIAN PHARMACOPEIA 2007" protocol, as we know that herbal Melting varies from component to component.

Solubility studies

A solubility study was executed as per the IP 2018. In this maximum number of solvents are required to dissolve the solute.

Thin layer chromatographic studies

Every solvent extract underwent thin layer chromatography (TLC) following the traditional one-dimensional ascending technique, with silica gel-G serving as the stationary phase.[19].

High-performance thin-layer chromatographic studies

Using silica gel-G as the stationary phase, every extract from a solvent was exposed to thin layer chromatography (TLC) in concert with the traditional one-dimensional ascending technique, and the developments were viewed under an ultraviolet (UV) light.





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***In vitro* methods employed for anti-hyperglycaemic activity**

Alpha-amylase enzyme inhibition: A 0.1% w/v starch solution was created by combining 0.1g of potato starch with 100 ml of a 16 mM sodium acetate buffer. The enzyme solution was formulated by blending 27.5 milligrams of alpha-amylase with 100 milliliters of purified water. A colorimetric reagent was produced by mixing a sodium potassium tartrate solution additionally three, five dinitro salicylic acid (96 mM). After the addition of the starch solution, the control and plant extracts were permitted to interpret with the alpha-amylase solution in an alkaline environment at 25°C. The reaction was evaluated after a period of three minutes. The transformation of 3, 5 dinitro salicylic acid into 3-amino-5-nitro salicylic acid indicated the production of maltose. This reaction can be observed at a wavelength of 540 nm^[2].

Inhibition of alpha-glucosidase enzyme

To investigate the inhibitory effect, a 0.2 M Tris buffer at pH 8.0 and Plant extract in various quantities were incubated with a 1 ml solution of starch substrate (2% w/v maltose or sucrose) for 5 minutes at 37°C. The reaction was set in motion by annexing one milliliter of alpha-glucosidase enzyme (1U/ml), followed by an additional incubation period of forty minutes at 35°C. The procedure was stopped by introducing two milliliters of 6N HCl. Subsequently, the color intensity was gauged at a wavelength of 540 nm.^[2]

Calibration curve of psidium guajava leaf extract

The methanolic extract of Psidium guajava was dissolved in a phosphate buffer with a pH of 6.8. This solution was then used to establish a calibration or standard curve for a UV-visible spectrophotometer within a wavelength range of 200–400 nm. Following this, the maximum wavelength (λ_{max}) of the Psidium guajava extract was ascertained.

Drug excipient compatibility studies

Fourier-transform infrared spectroscopy(FTIR)

The intention of this research was to detect any changes in the drug's chemical structure following its combination with the excipients. The compatibility among the Active Pharmaceutical Ingredient (API) and the excipients was assessed using FT-IR spectral analysis. Samples were collected for this FT-IR analysis. The IR spectra of the drug, encapsulated in KBr pellets, were recorded using FTIR (Bruker's FTIR) at a moderate scanning speed from 4000 to 400 cm⁻¹. The spectra showed peak values (wave number) along with potential functional groups, which were then compared to a reference value. The findings indicated that the substance was a pure aqueous extract when compared with the chemical structure^[20].

Differential scanning calorimetry(DSC)

Differential scanning calorimetry (DSC) is a tactics that investigates the thermal changes in a sample as it is heated. During the analysis, the sample and the reference are sustained at fairly the Unvaried in temperature. DSC aids in the study of phase transitions, such as melting and decomposition. DSC studies can be either exothermic or endothermic. For instance, when a substance transitions from a solid to a liquid state, it absorbs heat, necessitating additional heat to raise the sample's temperature to match that of the reference. DSC thermograms were acquired using a differential scanning calorimeter(Q20 from TA Instruments)^[21].

Optimization of Super disintegrant & Binder by using Design of experiments(3² factorial designs)

The goal of formulation optimization is to identify the values of formulation variables that enable the creation of an optimal pharmaceutical product. It's essential to understand the factors that could impact the characteristics of a new formulation. Furthermore, to attain the most effective formulation, tests involving combinations of variables necessitate a highly precise predictive model.^[22]. "The process of optimizing super-disintegrating agents employed a 3² Full factorial Design. Initial results informed the choice of Crospovidone (X1) and Microcrystalline cellulose (X2) as independent variables in the 3² factorial designs. Concurrently, Disintegration time (Y1), In-vitro Dissolution (Y2), and Friability (Y3) were treated as Dependent variables. The Design Expert 10.0 software was utilized to accomplish





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multi-linear regression analysis, ANOVA, and to generate graphical depictions of factor influences through contour plots. The experimental procedures and collected data for each of the 3² complete factorial design batches of *Psidium guajava* Linn's Fast Dissolving Tablets involved the use of 300 mg of methanolic leaf extract.

Formulation Development & preparation of Fast Dissolving Tablets Containing *Psidium guajava* Linn. methanolic leaf extract by Direct Compression Method

Fast-dissolving tablets incorporating *Psidium guajava* leaf methanolic extract were fabricated using the direct compression method. A selected three-level, two-factor experimental design (3² factorial design) was employed to optimize the formulation, detailing the proportions of the independent variables Crospovidone and Microcrystalline cellulose in the tablet formulation. The selected dependent variables included percent drug release, Disintegration Time, and Friability, as depicted in **Table 1**. The three levels of factor X1 (Crospovidone) and factor X2 (Microcrystalline cellulose), each at varying concentrations, laid the groundwork for the design of the *Psidium guajava* leaf methanolic extract fast-dissolving tablets. Employing specific combinations of the two variables, X1 and X2, in line with the 3² Factorial, nine unique formulations of these tablets were randomly produced in correspondence with the design. To pinpoint the optimal combination and concentration to acquire the specified disintegration time (response 1), drug release percentage (response 2), and friability (response 3) of the dosage forms, these were analyzed to determine the aggregate effects of X1 and X2. Precompression tests were conducted. Each component was passed through a 60-pound sieve prior to mixing. The components, which included lactose, microcrystalline cellulose, mannitol, and cross-povidone, were then blended using a mortar and pestle. Once the excipients were thoroughly mixed, the methanolic leaf extract powder of *Psidium guajava*, sodium saccharin, talc, and magnesium stearate were introduced. The drug and excipient blend from various batches were compressed into bland-faced tablets with an 11 mm diameter using a rotating single-station tablet punching machine, following the pre-compression studies as per the formulae in **Table 2**. [23]. Whereas the optimization of the formulation, a 3² factorial Design was chosen, with Crospovidone and microcrystalline cellulose selected as independent variables. The composition of formulations F1-F9 & C1 is provided in **Table 2**. The tablets were Stocked in well-sealed, waterproof canister.

Pre-compression studies

Before the aforementioned formulas were compressed into tablets, the mixed blends are subjected to pre compression evaluations. In these pre-compression studies, the prepared powder is assessed on several attributes such as the angle of repose, bulk density, tapped density, Carr's index, and Hausner's ratio[13].

Angle of Repose(θ)

Method: The widely recognized funnel method was employed. A flat surface, covered with graph paper, was arranged so that the funnel's tip was about 2 cm above it. The test sample consisted of ten grams of powder, which was permitted to pass across the funnel up till the conical pile's peak just reached the funnel's tip[24]. Using the following equation, the powder cone's height, diameter, and angle of repose (θ) were calculated. The angle of repose should be in virtue of limits mentioned in **Table 3**.

$$\tan \theta = h / r$$

Where, θ = angle of repose; h = height of the heap of powder; r = radius of the base of the powder

Bulk density(D_b)

An exact weight of the powder was moved through to a measuring cylinder. The volume and weight of the entire powder were then documented for the computation of the bulk density[24]. It is stated as gm/ml and given by formulae mentioned below,

$$D_b = M / V_o$$

Where, D_b = Bulk density (g/ml); M = weight of powder(g); V_o = bulk volume of powder(ml)





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Tapped density (D_t)

A measured volume of powder was introduced into a measuring cylinder, and after 100 taps, the powder's volume and the powder's total weight were recorded. This information was used to compute the powder's tapped density, which is expressed in g/ml and can be found using a Tapped Density Apparatus (LABINDIA, TD-1025, India)[24]. It is given by,

$$D_t = M / V$$

Where, D_t = Tapped density (g/ml), M = weight of powder (g), V = tapped volume of powder (ml)

Carr's Index/Compressibility Index

Another name for Carr's Index, which is derived from the bulk and tapped densities, is the Compressibility index. Assuming a subject matter is compressible, its flow ability should increase. A number of less than 20 indicates that a material is free-flowing [24]. (Table 4). The formula for Carr's Index is as follows-

$$\text{Carr's Index (\%)} = \frac{D_t - D_b}{D_t} \times 100$$

Hausner's ratio

This can be determined by the divide between the bulk and tapped densities, which provides an illustration of the powder's flow characteristics [24].

Hausner's ratio = Tapped density(D_t) / Bulk density(D_b)

Compression of FDT's

Among different compression techniques we selected direct compression method which is type of conventional techniques for preparation of FDT's using Rotatory Tablet punching machine as per composition mentioned in Table 2.

Post-compression studies

The sub sequent quality control tests were implemented on each of the prepared FDTs.

Weight variation

A digital balance was used to weigh twenty tablets at random from each formulation in order to guarantee that the weight of every tablet in the batch was the same. After that, the average weight variation was calculated[25].

Hardness

A tablet hardness tester was utilized to measure the hardness or crushing strength of the investigated fast dissolving tablet formulations. Testers from Pfizer, Monsanto, and other companies were used[25].

Friability test

A USP-style Roche friabilator was used to ascertain the friability of a batch of twenty fast dissolving tablets. Pre-weighed tablets were put in a polymer chambered friabilator and spun at 25 rpm for four minutes using a motor that was linked to the device[25]. The tablets were then reweighed, dedusted, and the formula was used to determine the percentage weight loss (friability).

$$\% \text{ Friability} = \frac{\text{Initial weight}(W1) - \text{Final weight}(W2)}{\text{Initial weight}(W1)} \times 100$$

Where, W1= Weight of tablet before test, W2 = Weight of tablet after test

Wetting time

A Petri dish with a diameter of 10 cm held five rounded tissue sheets. After that, ten milliliters of water containing 0.5% eosin—a dye that dissolves in water—were added to the plate. The purpose of this dye solution was to verify that the tablet's surface was completely moist. At a temperature of 25°C, a tablet was gently disposed on the surface of the tissue paper in the Petri dish. The wetting time was measured as the amount of time it took for the water to





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cover the tablets completely from top to bottom. A timer was utilized to record the wetting time for the six repetitions of this procedure[25].

Disintegration test

Using a 10-cm-diameter Petri dish with 10 ml of a pH 6.8 phosphate buffer at 25°C, the disintegration time (DT) of the fast-dissolving tablets was determined. Following careful placement of the tablet in the core of the Petri dish, the amount of time it took for the tablet to utterly break down into small fragments was noted[25].

In-Vitro dissolution test

Plant extract (API) from all formulations was subjected to in-vitro release tests using the paddle technique, in compliance with USP XVIII equipment II. The dissolving media consisted of 900 ml of pH 6.8 phosphate buffers, and the paddle speed was maintained at 50 rpm. Every two minutes, at predetermined intervals, 5 ml samples were collected and restored with an uniform volume of fresh medium. After passing these samples by the way of a Whatman filter paper, a UV-visible spectrophotometer was used to analyse the results. Expressing the drug concentration as a cumulative percentage of the drug dissolved, the data was attained using a standard calibration plot[25]. Drug Release Kinetics: Drug Release kinetics like Zero order, first order, Higuchi, koresmeyer, peppas, Hixson plots of optimized Formulation are plotted as per the above dissolution data.

Tablet thickness

After utilizing Vernier calipers to measure the thickness of six tablets, the average thickness value was calculated [26].

Accelerated Stability studies

Stability testing was performed to validate the physical, chemical, and physiological attributes of the product. As per ICH guidelines, accelerated stability testing was carried out at 40°C/75% RH to quickly ascertain the product's long-term stability. HDPE bottles, fitted with silica pads and containing tablets of the optimized formulation, were stored in stability chambers. Subsequently, the tablets' assay, appearance, and drug release were evaluated[26].

RESULTS

Preliminary tests for methanolic extract

preliminary phytochemical tests for psidium guajava Linn. Leaf extract is mentioned in below **Table 5**

Melting point

By using the capillary method, it was discovered that the melting point of Psidium guajava was found to be 220-230 °C.

Solubility

soluble in Distilled water, Methanol, Ethanol, 6.8 phosphate buffer & sparingly soluble in Acetone, Insoluble in chloroform

Thin layer chromatographic studies

plant extract and rutin are placed on a TLC plate for chromatographic separation.

High-performance thin-layer chromatographic studies

Rutin is taken as the standard compound for this HPTLC study and Rf values of the extracted sample and rutin have been compared for the conformation of the proximity of rutin in the extracted sample. The common Retention Factor of both the standard and sample was found to be 0.852 which indicates the proximity of rutin in plant extract as shown in **Figure 2**.





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***In vitro* methods employed for anti-hyperglycaemic activity**

Alpha-amylase enzyme inhibition

In-vitro studies for inhibition of Alpha-amylase enzyme are shown below in **Table 6**.

***In-vitro*, antidiabetic activity of alpha-glucosidase method**

In-vitro Studies for inhibition of Alpha-glucosidase Enzyme are shown below in **Table 7**.

Calibration curve of Psidium guajava methanolic leaf extract

To achieve 2,4,6,8, and 10 µg/ml, 10 mg of Psidium guajava Linn. is conjunction with 10 ml of pH 6.8 phosphate buffer. Two further serial dilutions are then carried out, and the UV-visible spectrophotometer's highest absorbance was calibrated at 215 nm. Plotting the graph included using absorbance on the y-axis and concentration on the x-axis. Beer-Lambert's law was followed by the graph, which was linear between 2 and 10 µg/ml. The calibrated curve of Psidium guajava methanolic leaf extract is constructed as shown below in **Figure 3**.

Drug excipient compatibility studies

Fourier Transform Infrared Spectroscopy (FTIR)

FTIR studies of API and API+EXCIPIENTS are shown in **Figure 4(a)** and **Figure 4(b)** respectively & Bands observed in FTIR Studies are shown in **Table 8**.

Differential scanning calorimeter(DSC)

Differential scanning calorimeter of Psidium guajava Linn. leaf extract(API) and Psidium guajava Linn. leaf extract(API)+Excipients are shown in **Figure 5(a)** and **figure 5(b)** respectively.

Pre-compression studies

The results of pre-compression studies of F1-F9 & C1 shows that All formulations have values within limits as per Indian pharmacopeia were shown in below **Table 9**.

Post-compression studies

The results of post-compression studies of formulations(F1-F9,C1) have values within limits as per Indian pharmacopeia were shown in **Table 10**.

Dissolution profile of formulations

Dissolution profile of different formulations was shown in **Table 11** & **Figure 6**.

***In vitro* Dissolution kinetic studies**

In *In-vitro* dissolution kinetic studies of C1 formulation which are shown in **Figure 7**, **Figure 8**, **Figure 9**, **Figure 10**, & **Figure 11**.

Experimental design and statistical data Analysis

The experiment's findings demonstrated how the amounts of crospovidone and microcrystalline cellulose impact the percentage of drug release, friability, and disintegration time. 3² factorial designs were conducted using the Design Expert 10.0 tool to optimize the ratio of Crospovidone to Microcrystalline cellulose. A range of disintegration times, drug release percentages, and friability were achieved in the production of fast-dissolving tablets. A significant quadratic model (p<0.05) was found after statistical analysis of the data for the drug release percentage (Y2), friability (Y3), and disintegration time (Y1) of the fast-dissolving tablets. Polynomial models have been developed for every response variable by the application of multiple linear regression analyses (MLRA). An illustration of how independent factors impact dependent variables is provided by the following polynomial equation:

$$Y=b_0+b_1X_1+b_2X_2+b_{12}X_1X_2+b_{11}X_1^2+b_{22}X_2^2$$





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Y in the equation above be regarded as the dependent variable, or response. Nine runs' intercept and arithmetic mean answers are both . For the linked components X1, X2, X1X2, X12, and X22, the calculated coefficients are b1, b2, b12, b11, and b22, in that order. The principal impacts of X1, X2, and X3 reflect the average result of progressively raising a single variable from a low to a high value. When variables are changed concurrently, the integration terms X1 and X2 show the variance in disintegration time, percent drug release, and friability; polynomial terms X12 and X22 define the quadratic effect. The coefficients of the polynomial equation show the antagonistic (represented by a -ve sign) and synergistic (represented by a +ve sign) consequences of the reactions. The expected R² of the model indicates how well the data fit the model. A problem with the model or the data may exist if the corrected R² and the forecasted R² do not agree within 0.20 of each other. A probability value (p<0.05) was used to represent the importance of the linked coefficient. Sufficient precision can be determined by a good signal-to-noise ratio. At the design sites, it compares the anticipated value range with the average prediction error. Ratios greater than four reveal that there is enough differentiation between the models. The model's significance (p<0.05) was assessed using a one-way ANOVA. Further investigation was conducted into the cumulative influence of independent variables on a selection of replies using response surface methodologies. Response surface approaches yield two-dimensional contour plots and three-dimensional response surface plots. While two-dimensional contour plots graphically depict response values, three-dimensional response surface plots shed light on the main and interaction impacts of independent variables. The data from the nine trial runs for each answer may be more easily seen thanks to the program's creation of contour plots and 3D response charts. The findings suggest that increasing the quantities of Crospovidone (X1) and Micro Crystalline Cellulose (X2) prompt to a decrease in friability, an increase in percent drug release, and a reduction in disintegration time for the Psidium guajava Linn extract fast-dissolving tablets. The disintegration time (Y1), drug release percentage (Y2), and friability (Y3) were measured using the Design Expert tool (version 10.0) to produce responses to an analysis of variance (ANOVA). Dependent factors including friability (Y3), drug release percentage (Y2), and disintegration time (Y1) are significant, according to the ANOVA table. The values were displayed in below. Analysis of Variance(ANOVA) of three responses are recorded. The values were displayed in the table. Analysis of Variance(ANOVA) of three responses is shown in **Table 12, Table 13, and Table 14**. Counter plot Obtained are shown in **Figure 12** , 3D surface plot are shown in **Figure 13**, and as well as overlay of Dependent variables was shown in **Figure 14**.

Drug Release Comparison between marketed FDT and optimized formulation FDT

A comparison of drug release between Marketed Fast Dissolving Tablet and C1 formulation is shown in **Figure 15**.

Accelerated Stability studies

Formulation C1 was put through to accelerated stability studies at 40°C/75% RH For observation. the formulation showed not much variations in any parameters. Accelerated stability studies of C1 was mentioned in **Table 15**.

DISCUSSION

Utilizing 3² factorial designs and the Design Expert 10.0 software, the study optimized formulae that combined microcrystalline cellulose with crospovidone. Friability, medication release, and disintegration time were assessed in experimental experiments. With ideal properties, the best formulation, C1, was found& was identified by the model, with characteristics of 0.52±0.010 seconds for friability, 93.8±0.014 % for drug release, and 38±1.0 seconds for disintegration time. When compared to other FDT formulations containing cross povidone & Microcrystalline cellulose in varying concentrations, formulation C1, a fast-dissolving tablet formulation comprising Psidium guajava Linn. methanolic Leaf Extract prepared by direct compression method, sprang up as the overall best formulation based on the Design of Experiment (DOE) & *in vitro* Antihyperglycemic activity & In-Vitro drug release characteristics (pH 6.8 buffer). Comparing these Psidium guajava leaf extract FDTs to commercially available anti-diabetic FDTs, it was discovered that they were biocompatible, safe, and effective quick dissolving.





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REFERENCES

1. Ochi, T., de Vos, S., Touw, D., Denig, P., Feenstra, T., & Hak, E. (2024, January 22). Tailoring Type II Diabetes Treatment: Investigating the Effect of 5-HTT Polymorphisms on HbA1c Levels after Metformin Initiation. *Journal of Diabetes Research*, 2024, 1–7. <https://doi.org/10.1155/2024/7922486>
2. Manikandan R, Anand AV, Muthumani GD. Phytochemical and in vitro anti-diabetic activity of methanolic extract of Psidium guajava leaves. *Int. J. Curr. Microbiol. App. Sci.* 2013;2(2):15-9.
3. Basha, S. K., & Kumari, V. S. (2012, January). In vitro antidiabetic activity of psidium guajava leaves extracts. *Asian Pacific Journal of Tropical Disease*, 2, S98–S100. [https://doi.org/10.1016/s2222-1808\(12\)60131-5](https://doi.org/10.1016/s2222-1808(12)60131-5)
4. Pan, D., Wang, H., Wu, S., Wang, J., Ning, Y., Guo, J., Wang, C., & Gu, Y. (2024, January 20). Unveiling the Hidden Burden: Estimating All-Cause Mortality Risk in Older Individuals with Type 2 Diabetes. *Journal of Diabetes Research*, 2024, 1–10. <https://doi.org/10.1155/2024/1741878>
5. Niskanen, L., Hannula, M., Kysenius, K., Kajjala, S., Lassenius, M. I., & Valle, T. T. (2024, January 25). Trends in clinical characteristics, medication use, and glycemic control in insulin-treated patients with type 1 and type 2 diabetes in Finland in 2012–2019: Nationwide real-world evidence study. *Journal of Diabetes*. <https://doi.org/10.1111/1753-0407.13491>
6. Roumie, C. L., Min, J. Y., D'Agostino McGowan, L., Presley, C., Grijalva, C. G., Hackstadt, A. J., Hung, A. M., Greevy, R. A., Elasy, T., & Griffin, M. R. (2017, April 5). Comparative Safety of Sulfonylurea and Metformin Monotherapy on the Risk of Heart Failure: A Cohort Study. *Journal of the American Heart Association*, 6(4). <https://doi.org/10.1161/jaha.116.005379>
7. Nagaraja, S., Ahmed, S. S., D. R., B., Goudanavar, P., M., R. K., Fattepur, S., Meravanige, G., Shariff, A., Shiroorkar, P. N., Habeebuddin, M., & Telsang, M. (2022, July 6). Green Synthesis and Characterization of Silver Nanoparticles of Psidium guajava Leaf Extract and Evaluation for Its Antidiabetic Activity. *Molecules*, 27(14), 4336. <https://doi.org/10.3390/molecules27144336>
8. Biswas, B., Rogers, K., McLaughlin, F., Daniels, D., & Yadav, A. (2013). Antimicrobial Activities of Leaf Extracts of Guava (*Psidium guajava* L.) on Two Gram-Negative and Gram-Positive Bacteria. *International Journal of Microbiology*, 2013, 1–7. <https://doi.org/10.1155/2013/746165>
9. Tella, T., Masola, B., & Mukaratirwa, S. (2022, May). Anti-diabetic potential of *Psidium guajava* leaf in streptozotocin induced diabetic rats. *Phytomedicine Plus*, 2(2), 100254. <https://doi.org/10.1016/j.phyplu.2022.100254>
10. Wang, L., Wu, Y., Bei, Q., Shi, K., & Wu, Z. (2017, August 31). Fingerprint profiles of flavonoid compounds from different *Psidium guajava* leaves and their antioxidant activities. *Journal of Separation Science*, 40(19), 3817–3829. <https://doi.org/10.1002/jssc.201700477>
11. Jaiarj, P., Khoohaswan, P., Wongkrajang, Y., Peungvicha, P., Suriyawong, P., Sumal Saraya, M., & Ruangsomboon, O. (1999, November). Anticough and antimicrobial activities of *Psidium guajava* Linn. leaf extract. *Journal of Ethnopharmacology*, 67(2), 203–212. [https://doi.org/10.1016/s0378-8741\(99\)00022-7](https://doi.org/10.1016/s0378-8741(99)00022-7)
12. Vanbillemont, B., & De Beer, T. (2020, October). Application of polyvinyl acetate in an innovative formulation strategy for lyophilized orally disintegrating tablets. *International Journal of Pharmaceutics*, 588, 119717. <https://doi.org/10.1016/j.ijpharm.2020.119717>



Sudheer Kumar Penumudi *et al.*,

13. Mansi Chadha*, Ujjwal Nautiyal., (2023, march 3) Formulation and Evaluation of Anti-Diabetic Tablet of Vildagliptin and Effect of Disintegrants Concentration on Drug Release. *Ymer*,2023, Volume 22: Issue 03 (Mar) – 2023.
14. Luo, Y., Peng, B., Wei, W., Tian, X., & Wu, Z. (2019, April 5). Antioxidant and Anti-Diabetic Activities of Polysaccharides from Guava Leaves. *Molecules*, 24(7), 1343. <https://doi.org/10.3390/molecules24071343>
15. Patel, V., & Gupta, M. M. (2013, March 15). FORMULATION AND EVALUATION ORAL DISPERSIBLE TABLET OF CINNARIZINE. *Journal of Drug Delivery and Therapeutics*, 3(2). <https://doi.org/10.22270/jddt.v3i2.450>
16. Sharma A, Jain A, Purohit A, Jatav R, Sheorey RV. Formulation and evaluation of aceclofenac fast dissolving tablets. *Int J Pharm & Life Sci*. 2011 Apr;2(4):681-6.
17. Ekom, S. E., & Tamokou, J. D. D. (2018, July 10). Methanol Leaves Extract of *Psidium guajava* Linn. Exhibited Antibacterial and Wound Healing Activities. *International Journal of Current Microbiology and Applied Sciences*, 7(07), 4008–4023. <https://doi.org/10.20546/ijcmas.2018.707.467>
18. Dhiman, A., Nanda, A., Ahmad, S., & Narasimhan, B. (2011). In vitro antimicrobial activity of methanolic leaf extract of *Psidium guajava* L. *Journal of Pharmacy and Bioallied Sciences*, 3(2), 226. <https://doi.org/10.4103/0975-7406.80776>
19. Sarkar J, Pal S, Bhattacharya S, Biswas M. Thin layer chromatographic profiling and evaluation of analgesic activity of *Psidium guajava* leaf extracts in mice. *J. Adv. Pharm. Edu. Res*. 2011;1(3):177-83.
20. Chandira M, Jayakar B. Formulation and evaluation of herbal tablets containing *Ipomoea digitata* Linn. extract. *Extraction*. 2010 Jul;3(1):022.
21. Ekere, K. E., Isimi, Y. C., Okoh, J. E., Olobayo, K. O., & Emeje, M. O. (2017, September). Differential scanning calorimetry and thin layer chromatography: Emerging tools for predicting stability of herbal products. *Journal of Herbal Medicine*, 9, 74–80. <https://doi.org/10.1016/j.hermed.2017.02.001>
22. Fouad, S. A., Malaak, F. A., El-Nabarawi, M. A., & Abu Zeid, K. (2020, December 31). Development of orally disintegrating tablets containing solid dispersion of a poorly soluble drug for enhanced dissolution: In-vitro optimization/in-vivo evaluation. *PLoS ONE*, 15(12), e0244646. <https://doi.org/10.1371/journal.pone.0244646>
23. Srinivasan, S., Elumalai, K., Cherian, B. V., & Ramanujam, S. K. (2023, October). Formulation and characterization of metformin hydrochloride orodispersible tablets with super disintegrants. *Intelligent Pharmacy*, 1(3), 162–166. <https://doi.org/10.1016/j.ipha.2023.06.006>
24. Basavaraj BV, Naramsetty S. VignaMungo Mucilage-A Natural Polyme r in the Design of Matrix Based SR Tablet of Aceclofenac. *Inter J Pharm Sci Re v Res*. 2013;21:125-30.
25. Basu, B., Bagadiya, A., Makwana, S., Vipul, V., Batt, D., & Dharamsi, A. (2011). Formulation and evaluation of fast dissolving tablets of cinnarizine using superdisintegrant blends and subliming material. *Journal of Advanced Pharmaceutical Technology & Research*, 2(4), 266. <https://doi.org/10.4103/2231-4040.90885>
26. Paul Y, Tyagi S, Singh B. Formulation and evaluation of oral dispersible tablets of zidovudine with different superdisintegrants. *International Journal of Current Pharmaceutical Review and Research*. 2011 May;2(2):80-5.

Table 1: Experimental design layout

Formulation code	Run	Coded Factor X1	Coded Factor X2	Factor X1: cp (mg)	Factor X2: mcc (mg)
F1	1	-1	-1	40	100
F2	2	-1	0	40	90
F3	3	-1	+1	40	80
F4	4	0	-1	30	100
F5	5	0	0	30	90
F6	6	0	+1	30	80
F7	7	+1	-1	20	100
F8	8	+1	0	20	90
F9	9	+1	+1	20	80



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Table 2: Compositions of Fast Dissolving Tablets (F1-F9 & C1)

Ingredients	Formulation no.									
	Quantity per tablet (in mg)									
	F1	F2	F3	F4	F5	F6	F7	F8	F9	C1
Psidiumguajava methanolic Leaf extract	300	300	300	300	300	300	300	300	300	300
Cross povidone	40	40	40	30	30	30	20	20	20	40
Mannitol	60	60	60	60	60	60	60	60	60	60
MicroCrystalline Cellulose(MCC)	100	90	80	100	90	80	100	90	80	93
Saccharin sodium	3	3	3	3	3	3	3	3	3	3
Lactose	12	12	12	12	12	12	12	12	12	12
Talc	2	2	2	2	2	2	2	2	2	2
Magnesium Stearate	3	3	3	3	3	3	3	3	3	3

Table 3: Limits of the angle of Repose(θ)

Flow property	Angle of repose (degrees)
Excellent	25–30
Good	31–35
Fair- aid not needed	36–40
Passable- may hang up	41–45
Poor--must agitate, vibrate	46–55
Very poor	56–65
Very, very poor	>66

Table 4:Scale of Flow ability

Compressibility Index (%)	Flow Character	Hausner's Ratio
10	Excellent	1.00–1.11
11–15	Good	1.12–1.18
16–20	Fair	1.19–1.25
21–25	Passable	1.26–1.34
26–31	Poor	1.35–1.45
32–37	Very poor	1.46–1.59
>38	Very, very poor	>1.60

Table 5:preliminary tests for Phyto chemical screening

S.no	Phytochemical constituents	Name of tests	Methanolic extract
1	Alkaloids	Mayer's test Picric acid test	+ +
2	Carbohydrate	Molisch test	+
3	Tannin	Lead acetate test	+
4	Steroidal glycosides	Salkowski test	+
5	Saponin glycosides	H ₂ SO ₄ test	+
6	Flavonoids	Shinoda's test	+
7	Chlorogenic acid	Ammonia	-
8	Phenols	FeCl ₃ test	+
9	Coumarin	NaCl test	+
10	Chlorogenic acid	Ammonia	-

+ = Present , - = Absent



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Table 6: Inhibition of Alpha-amylase enzyme

Sl.no	Concentration of sample(ml)	% of Enzyme Inhibition
1	0.2	35.6
2	0.4	49.1
3	0.6	68.5
4	0.8	87.1
5	1.0	95.4

Table 7: Inhibition of Alpha-glucosidase enzyme

Sl.no	Concentration of sample(ml)	% of Enzyme Inhibition
1	0.2	33.8
2	0.4	52.6
3	0.6	65.3
4	0.8	78.5
5	1.0	88.2

Table 8: Reported and observed FT-IR frequencies of pure drug and pure drug + Excipients

Bond	Characteristic bond(cm^{-1})	Observed bands of the pure drug (cm^{-1})	Observed bands of pure drug + Excipients (cm^{-1})
Alkyl C-H Stretch	2950-2850	2930.72	2850.83,2917.09
Aromatic C=C Bending	1700-1500	1523.10,1612.90,1696.12	1540.13,1630.27
Carboxylic Acid O-H Stretch	3000-2500	2930.72	2850.83,2917.09
Ketone C=O Stretch	1750-1680	1696.12	1749.19

Table 9: pre-compression studies of F1-F9 & C1 formulations

Formulae	Bulk density (g/cm^3)	Tapped density (g/cm^3)	Carr's index (%compressibility factor)	Hausner's Ratio(g/mL)	Angle of Repose($\tan\theta=h/r$)
F1	0.59±0.0153	0.69±0.0058	14.4±0.4041	1.169±0.0021	33.4±0.251 ($\tan\theta=0.659$)
F2	0.56±0.0361	0.65±0.0400	13.8±0.3786	1.160±0.0036	36.3±0.3055 ($\tan\theta=0.734$)
F3	0.58±0.0265	0.66±0.0252	12.1±0.2517	1.137±0.0025	27.2±0.2082 ($\tan\theta=0.513$)
F4	0.53±0.0252	0.60±0.0153	11.66±0.0208	1.132±0.0015	27.7±0.3055 ($\tan\theta=0.525$)
F5	0.54±0.0153	0.60±0.0208	10±0.2517	1.111±0.0020	25.1±0.2517 ($\tan\theta=0.468$)
F6	0.55±0.0252	0.63±0.0100	12.6±0.200	1.145±0.0030	27.8±0.2082 ($\tan\theta=0.527$)
F7	0.57±0.0100	0.66±0.0404	13.6±0.3606	1.157±0.0015	31.6±0.2517 ($\tan\theta=0.615$)
F8	0.52±0.0200	0.61±0.0252	14.7±0.4509	1.070±0.0026	35.1±0.2082 ($\tan\theta=0.702$)
F9	0.60±0.0306	0.71±0.0200	15.4±0.3000	1.183±0.0025	38.9±0.4583 ($\tan\theta=0.806$)





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C1	0.57±0.0058	0.64±0.0252	10.93±0.1850	1.122±0.0050	25.5±0.4000 (tanθ-0.478)
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The means ± standard deviations were used to express all the data (n = 3).

Table 10: F1-F9 & C1 post-compression studies values

Post-compression studies	F1	F2	F3	F4	F5	F6	F7	F8	F9	C1
Weight variation (%)	2.76±0.0 451	2.99±0.0 200	3.26±0.0 200	3.79±0.0 100	3.92±0.0 100	3.63±0.0 246	3.89±0.0 100	4.05±0.0 0115	4.69±0.0 200	3.14±0.0 404
Hardness (kg/cm ²)	4.6±0.35 12	4.1±0.05 77	3.9±0.00 58	4.5±0.10 00	4.0±0.10 00	3.7±0.15 28	4.3±0.15 28	3.9±0.3 000	3.5±0.40 00	4.4±0.16 92
Thickness (mm)	2.6±0.15 28	2.8±0.10 00	2.6±0.15 28	2.5±0.10 00	2.7±0.25 17	2.4±0.30 00	2.5±0.20 00	2.6±0.2 517	2.9±0.15 28	2.7±0.10 00
Friability (%)	0.45±0.0 100	0.57±0.0 200	0.64±0.0 200	0.43±0.0 200	0.58±0.0 100	0.66±0.0 100	0.42±0.0 100	0.6±0.0 200	0.69±0.0 300	0.52±0.0 100
Wetting time(sec)	43±1.000 0	31±1.000	25±1.00 0	42±1.00 0	33±1.00 0	26±1.00 0	44±1.00 0	36±1.0 00	23±1.00 0	34±1.00 0
Disintegration time(sec)	45±0.577 4	36±1.000 0	27±0.51 32	47±1.00 0	39±1.00 0	28±1.00 0	49±1.00 0	40±1.0 00	29±0.57 74	38±1.00 0
%Drug Release (%)	89.513±0.0008	90.189±0.0013	90.91±0.0437	94.81±0.0141	90.48±0.0210	85.09±0.0319	86.88±0.0163	71.4±0.2787	67.47±0.0308	93.68±0.0141

Every single data point was represented as the average ± standard deviation. Hardness, friability, thickness, wetting time, also weight fluctuation (n = 20), as well as disintegration time and % drug release (n = 6).

Table 11: In vitro Dissolution Studies (%drug release) of all Formulations

Formulation Time(min)	F1	F2	F3	F4	F5	F6	F7	F8	F9	C1
0	0	0	0	0	0	0	0	0	0	0
2	22.321	26.786	33.9	44.64	43.75	47.32	44.11	59.64	55.18	45.71
4	26.731	30.506	36.79	56.32	53.64	54.73	55.42	61.22	56.02	53.82
6	38.665	43.175	52.17	64.49	62.15	60.57	62.87	64.42	57.04	67.03
8	50.763	58.195	61.192	74.89	74.68	71.65	71.65	67.1	58.57	72.09
10	65.049	70.517	78.69	83.11	80.93	74.86	75.93	69.07	60	86.97
12	89.513	90.189	90.91	94.81	90.48	85.09	86.88	71.4	67.47	93.68

All values mentioned in above table are described as percentage(%) only

Table 12: Analysis of Variance of Response Disintegration Time (Y1)

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	558.17	2	279.08	494.11	<0.0001	significant
A-Crospovidone	16.67	1	16.67	29.51	0.0016	
B-MCC	541.50	1	541.50	958.72	<0.0001	
Residual	3.39	6	0.5648			
Cor Total	561.56	8				





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Table 13: Analysis Variance of response % Drug Release i.e. invitro dissolution(Y2)

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	463.62	2	231.81	5.79	0.0398	significant
A-Crospovidone	335.43	1	335.43	8.37	0.0276	
B-MCC	128.19	1	128.19	3.20	0.1238	
Residual	240.33	6	40.06			
Cor Total	703.95	8				

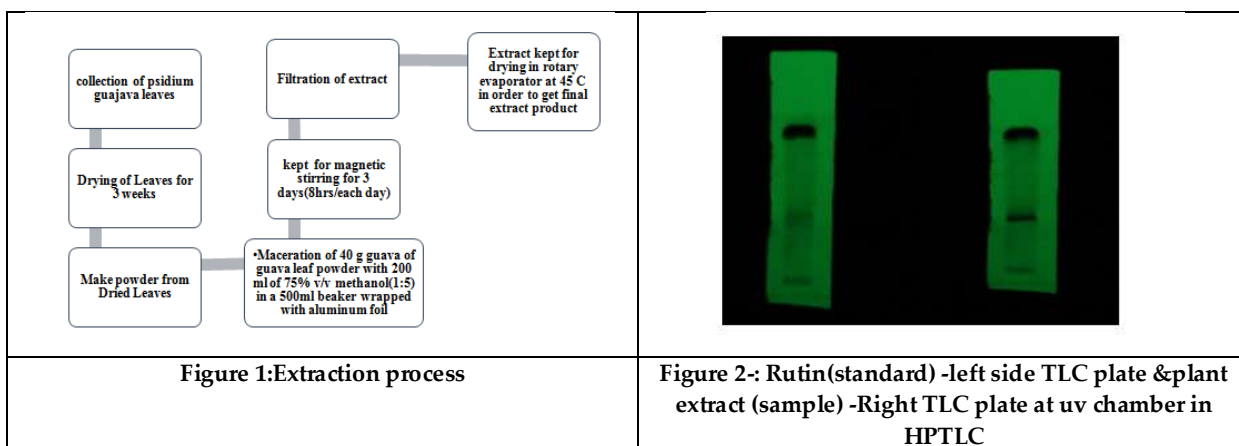
Table 14: Analysis Variance of response Friability(Y3)

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	0.0798	2	0.0399	56.53	0.0001	significant
A-Crospovidone	0.0004	1	0.0004	0.5906	0.4714	
B-MCC	0.0794	1	0.0794	112.46	<0.0001	
Residual	0.0042	6	0.0007			
Cor Total	0.0840	8				

Table 15: Accelerated Stability Studies of C1

S.no	Parameter	Initial	Stored at 40°C ± 2°C and 75% ± 5% RH					
			In months					
			1	2	3	4	5	6
1	weight variation(%)	3.14±0.0404	3.14±0.0402	3.14±0.0400	3.14±0.0401	3.14±0.398	3.14±0.387	3.14±0.389
2	Friability (%)	0.52±0.0100	0.51±0.0101	0.53±0.0101	0.52±0.0102	0.53±0.0102	0.50±0.0102	0.51±0.0103
3	Hardness (kg/cm ²)	4.4±0.1692	4.22±0.0252	4.21±0.0208	4.23±0.651	4.20±0.0451	4.23±0.0351	4.21±0.0400
4	Disintegration Time(sec)	38±1.000	36±0.98	38±1.000	37±1.10	39±1.21	37±0.997	38±1.121
5	Invitro Drug release(%)	93.68±0.0141	93.66±0.0392	93.65±0.0668	93.61±0.243	93.63±0.261	93.62±0.0179	93.60±0.0301

Every single data point was represented as the average ± standard deviation. Variations in weight (n = 20), hardness, friability, moreover wetting time (n = 3), as well as disintegration time and percent drug release (n = 6), are investigated.





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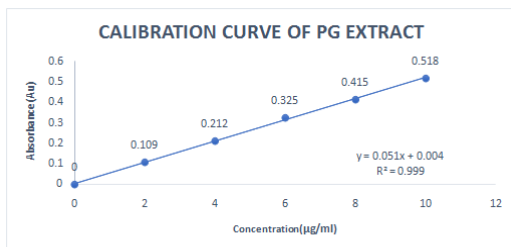


Figure 3: calibration curve of *Psidium guajava* methanolic leaf extract

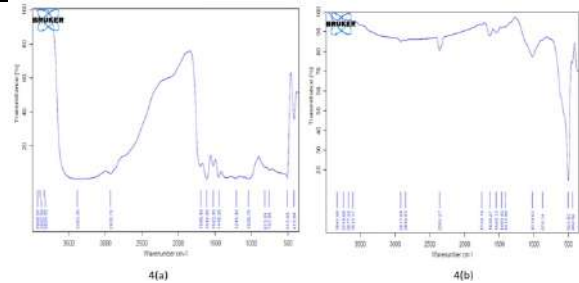


Figure 4:(a)-FTIR studies on *Psidium guajava* methanolic leaf extract(API)
4(b)- FTIR studies of *Psidium guajava* methanolic leaf extract (API)+ Excipients

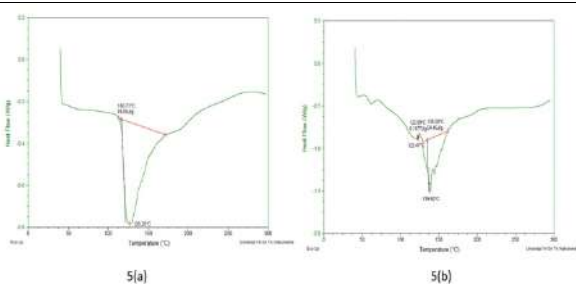


Figure 5:5(a)Thermogram of Pg Linn. methanolic leaf extract (API)
5(b)Thermogram of Pg Linn. methanolic leaf extract (API)+ Excipients

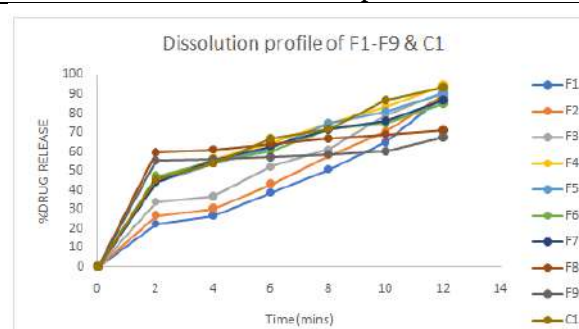


Figure 6:Dissolution profile of different formulations

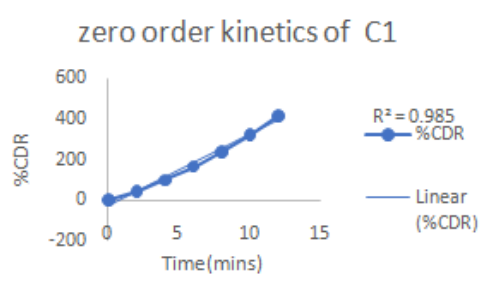


Figure 7-zero order kinetics

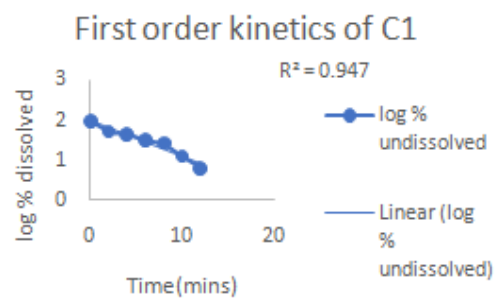


Figure 8-First order kinetics



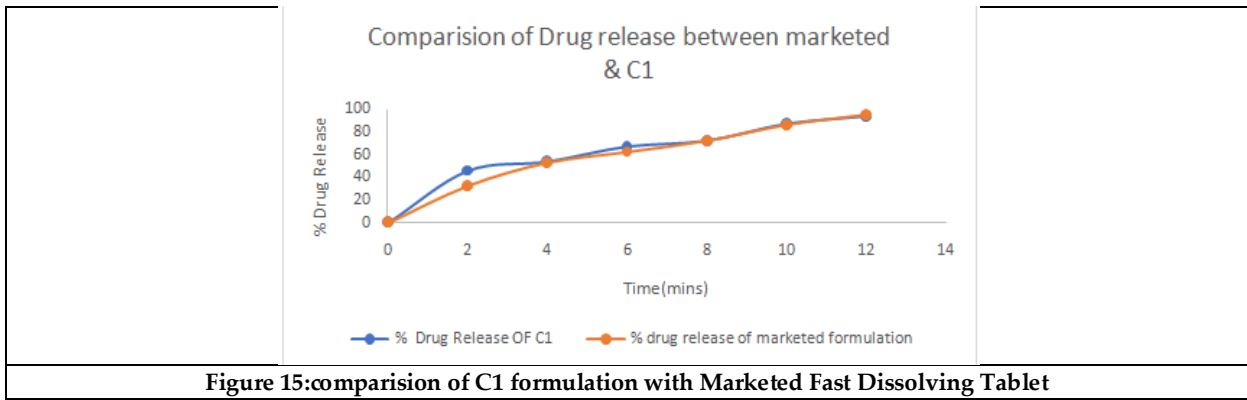


<p>Higuchi plot of C1</p> <p>$R^2 = 0.840$</p> <p>● c %dr</p> <p>— Linear (c %dr)</p>	<p>peppas plot of C1</p> <p>$R^2 = 0.874$</p> <p>● log t</p> <p>— Linear (log t)</p>
<p>Hixson-crowell of C1</p> <p>$R^2 = 0.966$</p> <p>● cube root of % remaining drug</p> <p>— Linear (cube root of % remaining drug)</p>	<p>Figure 12(a) contour plot for Disintegration time 12(b) contour plot for % Drug release (In vitro dissolution) 12(c) contour plot for Friability (%)</p>
<p>13(a) 13(b) 13(c)</p>	<p>Overlay Plot</p> <p>Legend: Disintegration time: 38.1359 In vitro dissolution: 83.8623 Friability: 0.526437 n: 40 ID: 82.1882</p>
<p>Figure 13: 13(a) 3D surface plot for disintegration time 13(b) 3D surface plot for % drug Release (In vitro dissolution) 13(c) 3D surface plot for friability (%)</p>	<p>Figure 14: Overlay plot of Y1, Y2, Y3 Responses due to effect of X1 & X2 Factors</p>





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How Much Carbon Footprint Does A Household Emit? A Comparative Research between Low and High-Income Households

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ABSTRACT

Carbon emissions are one of the greatest environmental challenges in recent years as with rising worldwide living standards, increased energy consumption, and widespread usage of life-comforting commodities, it's important to assess the environmental impact of energy supply systems. India's vast population contributes to high CO₂ emissions, and the carbon footprint is a crucial metric for addressing climate change and promoting environmental sustainability. This research focuses on the computation of carbon footprint leaves by the different group of households in the selected study area. The carbon footprints left by utilizing several necessities such as electricity, LPG, coal, wooden pallets, and motor vehicles have been compared between rich and poor homes in this study. A total of 36 households were surveyed based on their annual incomes. According to this study, the carbon footprint of the wealthy is higher than that of the poor. Rich people's opulence and comfort-enhancing technologies release more carbon dioxide into the atmosphere. Now is the moment to consider the environment and the global goal of reducing these types of carbon emissions in order to attain net zero carbon emissions by 2050.

Keywords: Carbon footprint, carbon emission climate change, sustainability.

INTRODUCTION

Carbon footprints can be classified into various forms based on the activities or industries that generate emissions. This includes emissions caused directly by an individual or business, such as driving a car or burning fossil fuels [1] [4]. Associated with behaviors that indirectly contribute to carbon footprints, such as purchasing goods and services produced using high-energy procedures. Aside from this, an individual's activities such as transportation, energy



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consumption, nutrition, and waste creation are key sources of carbon emissions [6] [10]. The analysis of carbon emissions and carbon footprints is constantly linked to climate change [1]. The ecology and environment are directly impacted by the carbon footprint, or carbon emissions, that are accumulated in the atmosphere from different activities or any organization [14]. Climate change is among the most pressing issues facing humanity. It develops into a wide range of topics, including the environment, society, technology, and economy [15]. Reducing the impact of climate change is essential for equitable and sustainable development. Future national contributions to the build-up of GHG emissions in the earth's atmosphere will be crucial in preventing global warming from rising above 2° Celsius above preindustrial levels [4].

LITERATURE REVIEW

The term "carbon footprint" has gained popularity in recent years, and it now plays an important role in our planet's environmental implications. With global warming and climate change affecting the environment, carbon footprint assessments are in high demand nowadays. The carbon footprint of various types of activities, such as individuals, governments, organizations, production and processes, industry sectors, etc. Different approaches, methods, and technologies are used to calculate carbon footprints. Carbon footprint refers to the amount of gaseous emissions that are significant to climate change and are directly or indirectly caused by human production or consuming activities [15]. Cities are becoming a source of numerous types of population in our environment as their populations grow and industrial activities expand. Conduct a door-to-door survey of an individual's carbon footprint at the household level in a few locations in Mumbai and surrounding rural environs, as well as carbon footprints seen among the various economic classes. Carbon footprints are calculated using selected sources such as power, transportation, food consumption items, cooking fuel, and so on. According to the report, the average yearly per capita carbon footprint was 2.5 tons CO₂e in urban areas and 0.85 CO₂e in rural areas. Cooking fuel is the most important source of energy in rural areas, whereas electricity and transportation are the most important in cities [3].

Household emissions are a substantial impact to the environment, and they are assessed as per capita carbon footprints. Carbon footprint is the total amount of greenhouse gas emissions produced directly or indirectly by an organization or people. This study assessed the rural and urban carbon footprints of the sample household in West Bengal, India. In this study, multiple carbon emission parameters were used to calculate home per capita carbon footprint, and the findings revealed that cooking activities generate the most emissions in rural areas, whereas food activities generate the most emissions in urban households [7]. Carbon footprint refers to the overall GHG emissions caused by various stages of the life cycle, such as transportation, production, electricity, food preparation, and so on. The carbon footprint of food products occurs throughout their life cycle. Animal food products, such as meat and milk, and rice cultivation, in particular, emit methane, while food crops emit nitrous oxide and carbon dioxide as a result of crop cultivation, production, processing, and preparation. Carbon emissions occur at several stages of the food product life cycle. According to the findings of this study, changing our eating habits or purchasing food products with lower environmental impact is one way to minimize GHG emissions [13].

METHODOLOGY AND DATA COLLECTION

This study focuses on the carbon footprint that households leave when they consume resources such as electricity, LPG, fuels, firewood, and motor vehicles. The questioned households are classified into five income classes based on their annual incomes. A total of 36 families were surveyed using a questionnaire to evaluate their usage. Following this, the data were entered into the carbon footprint calculator to calculate the overall carbon footprint of homes.

Study Area

The selected households are from the Sivasagar district of Assam, India, and are geographically located in the north-eastern part of the Indian state of Assam. Sivasagar district is geographically located from 26.45 to 27.15 latitude and



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from 94.25 to 95.25 longitude, with a total population of 1,040,954. The monsoonal climate predominately covers the climatic conditions with the availability of the Brahmaputra River in the north.

RESULTS AND DISCUSSION**Carbon footprint by household items excluding vehicles:**

A person, organization, event, or product's direct or indirect contribution to greenhouse gas emissions, mainly carbon dioxide (CO₂), is measured by their "carbon footprint". It includes emissions from a variety of activities, including energy usage, transportation, food production, and more, and is expressed in units of carbon dioxide equivalent [6]. The entire amount of carbon dioxide emissions, either directly or indirectly resulting from an action or accumulated during a product's life, is measured as the carbon footprint[15]. Numerous gases, including carbon dioxide (CO₂), sulfur hexafluoride (SF₆), methane (CH₄), hydrofluorocarbons (HFCs), nitrous oxide (N₂O), and others, are considered greenhouse gases. Among them, CO₂ contributes more than the other gases due to its higher rate of release. Human activity has been identified as a major source of CO₂ emissions. Examples of these activities include burning fuel when operating vehicles, producing electricity, building, and other industrial processes[14]. Electricity is one of the resources that is absolutely necessary for human life cycles. which are primarily produced by the thermal station that runs on coal, and the earth's atmosphere is significantly impacted by this combustion [10]. Some resources, including fuels, LPG, electricity, etc., become necessities for human habitation. LPG can occasionally become unaffordable for low-income households because of its high cost. They are thus compelled to employ the antiquated cooking technique and other related practices on wooden pallets [1]. The table above shows the average carbon footprint of stratified different income class households. Despite using more firewood for cooking, low-income households leave a smaller footprint than high-income households. The major differences have been created because of the total electricity used by the households. High-income households consume more electricity, LPG, and coal in comparison to poor people.

Carbon footprint by vehicles

Motorization poses a significant carbon dioxide challenge in addition to typical transportation and development issues [2] [11]. Transportation-related activities are the main source of carbon dioxide emissions that contribute to carbon footprint [8]. Efforts to minimize carbon emissions from motor vehicles include the development and use of cleaner fuel technologies such as electric vehicles (EVs), hybrid vehicles, and vehicles powered by biofuels, hydrogen, and natural gas. Furthermore, advances in engine efficiency and pollution control technologies, as well as laws targeted at boosting fuel efficiency requirements and limiting vehicle miles driven, are essential initiatives for reducing the environmental impact of motor vehicles. The above table indicates that wealthier people contribute more carbon to the environment through their motor cars. Richer households emit an average of 1.53 metric tons of carbon from their four-wheeler automobile. This table illustrates that low-income households produce only 0.01 metric tons of carbon, whereas wealthy class 5 households contribute more than 200%. It is evident that carbon emissions grow with income level.

Average overall carbon footprint

There is a clear proportionality between rising CO₂ levels and rising earth's temperature. This worldwide rise in temperature is referred to as global warming [1] [5]. This results in variations in temperature, humidity, wind direction, precipitation, soil moisture content, and sea level. It also sets off numerous calamities such as extreme weather occurrences. Reducing carbon emissions is crucial for the fight against global warming [9] [11] [12]. Figure 3 displays emissions from both domestic items and motor vehicles. Low-income households emit less carbon dioxide into the atmosphere, and vice versa. Motor vehicles provide a bigger share of carbon emissions. Richer class households have a larger footprint than the next lowest income level.



**Bhagya Das and Olimpiya Borgohain****Sustainability Rating**

Sustainability clearly demonstrates how we ought to use our resources wisely so they last for future generations [9] [12]. By employing strategic choices, the carbon footprint values can also forecast future risk implications and current repercussions. Figure 4 compares the footprint to national and global averages for carbon emissions. The research area emits an average of 0.99 metric tons of carbon into the environment. The investigated area differs greatly from the national average due to a lack of industrial areas and a low population, both of which contribute significantly to carbon emissions. This footprint will be greater if all carbon emissions from all direct and indirect sources of human subsistence are included. CO₂ emissions must be decreased by collaborative efforts between the administration and the general public.

CONCLUSION

Every human being has the right to live in a "cleaner and safer environment," and we are largely responsible for the development of this notion and cause. Carbon emissions have become one of the most serious problems in recent years, and we must take every possible action to reduce them. Industrialization, modernization, and deforestation result in significant increases in carbon levels and trigger global warming and climate change. There is a need to adopt more efficient, low-fuel technologies that have a lower environmental and ecological impact. There is also a need for strict policy frameworks to regulate carbon emissions.

REFERENCES

1. Bailis, R., Drigo, R., Ghilardi, A., & Masera, O. (2015). The carbon footprint of traditional woodfuels. *Nature Climate Change*, 5(3), 266-272.
2. Bhautmage, U. P., Tembhurkar, A. R., Sable, A., Sinha, S., & Adarsh, S. (2015). Carbon Footprint for Transportation Activities of an Institutional Campus. *J. Energy Environ. Carbon Credit*, 5, 9-19.
3. Bhojar, S. P., Dusad, S., Shrivastava, R., Mishra, S., Gupta, N., & Rao, A. B. (2014). Understanding the impact of lifestyle on individual carbon-footprint. *Procedia-Social and Behavioral Sciences*, 133, 47-60.
4. Caro, D. (2018). Carbon Footprint. *Encyclopedia of Ecology*, 2nd Edition. <https://doi.org/10.1016/B978-0-12-409548-9.10752-3>
5. Fenner, A. E., Kibert, C. J., Woo, J., Morque, S., Razkenari, M., Hakim, H., & Lu, X. (2018). The carbon footprint of buildings: A review of methodologies and applications. *Renewable and Sustainable Energy Reviews*, 94, 1142-1152.
6. Gao, T., Liu, Q., & Wang, J. (2014). A comparative study of carbon footprint and assessment standards. *International Journal of Low-Carbon Technologies*, 9(3), 237-243.
7. Hazra, N. D. (2024). Rural and Urban Household Carbon Footprint: A Comparative Study, West Bengal, India. *Sustainability, Agri, Food and Environmental Research*, 12(1).
8. Lenzen, M., Sun, Y. Y., Faturay, F., Ting, Y. P., Geschke, A., & Malik, A. (2018). The carbon footprint of global tourism. *Nature climate change*, 8(6), 522-528.
9. Mancini, M. S., Galli, A., Niccolucci, V., Lin, D., Bastianoni, S., Wackernagel, M., & Marchettini, N. (2016). Ecological footprint: refining the carbon footprint calculation. *Ecological indicators*, 61, 390-403.
10. Matthews, H. S., Hendrickson, C. T., & Weber, C. L. (2008). The importance of carbon footprint estimation boundaries.
11. Müller, L. J., Kästelhön, A., Bringezu, S., McCoy, S., Suh, S., Edwards, R., ... & Bardow, A. (2020). The carbon footprint of the carbon feedstock CO₂. *Energy & Environmental Science*, 13(9), 2979-2992.
12. Pandey, D., Agrawal, M., & Pandey, J. S. (2011). Carbon footprint: current methods of estimation. *Environmental monitoring and assessment*, 178, 135-160.
13. Pathak, H., Jain, N., Bhatia, A., Patel, J., & Aggarwal, P. K. (2010). Carbon footprints of Indian food items. *Agriculture, ecosystems & environment*, 139(1-2), 66-73.





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14. Wandana, L. S., Wadanambi, R. T., Preethika, D. D. P., Dassanayake, N. P., Chathumini, K. K. G. L., &Arachchige, U. S. P. R. (2021). Carbon footprint analysis: promoting sustainable development. Journal of Research Technology and Engineering, 2(1), 73-80.
15. Wiedmann, T., & Minx, J. (2008). A definition of ‘carbon footprint’. Ecological economics research trends, 1(2008), 1-11.
16. <https://www.carbonfootprint.com/calculator.aspx>

Table 1: Stratified annual income of surveyed households

Class	Incomes	No. of Surveyed Households
1	0-1,00,000	9
2	1,00,000-3,00,000	7
3	3,00,000-5,00,000	12
4	5,00,000-7,00,000	5
5	Above 7,00,000	3

Table 2: Showing the carbon footprint by resources used by the households

Class	Average footprint				Total average carbon footprint(metric tons of CO2e)
	Electricity (Kwh)	LPG (litres)	Coal (tonnes)	Wood (tonnes)	
1	42.33	15	0	2.5	0.07
2	63.14	25	0	1	0.09
3	70.12	30	0	0.5	0.10
4	80.2	30	0.1	0.5	0.25
5	110.33	50	0.1	0	0.30

Table 3: Showing carbon footprint by motor vehicles

Class	Average footprint			Total average carbon footprint(metric tons of CO2e)
	Car	Motorbike up to 125cc	Motorbike above 125cc to 500cc	
1	0	0.01	0	0.01
2	0	0.37	0.27	0.64
3	0.64	0.12	0.38	1.14
4	0.52	0.31	0.40	1.24
5	1.53	0.32	0.43	2.28





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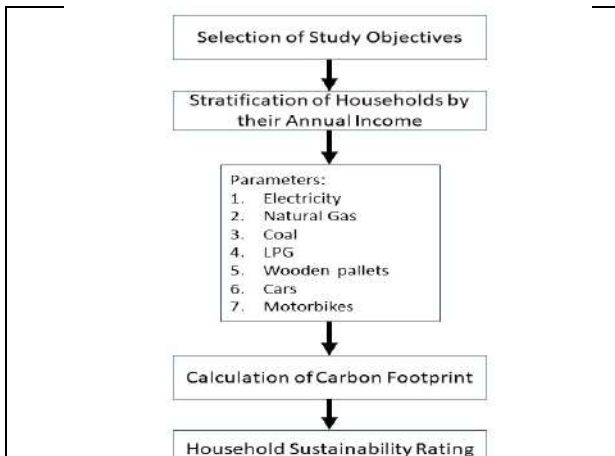


Figure 1: Showing methodology flowchart

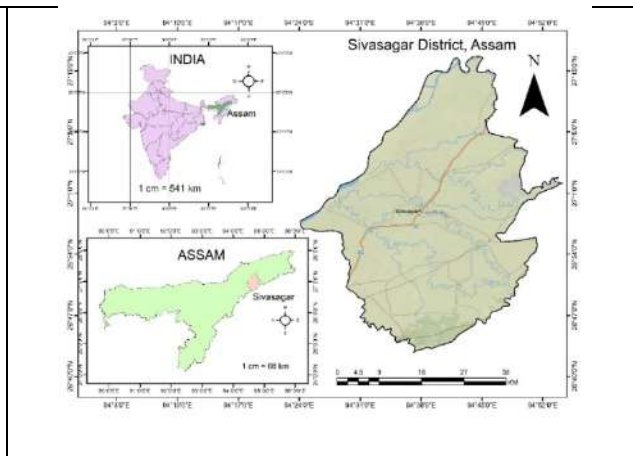


Figure 2: Study area

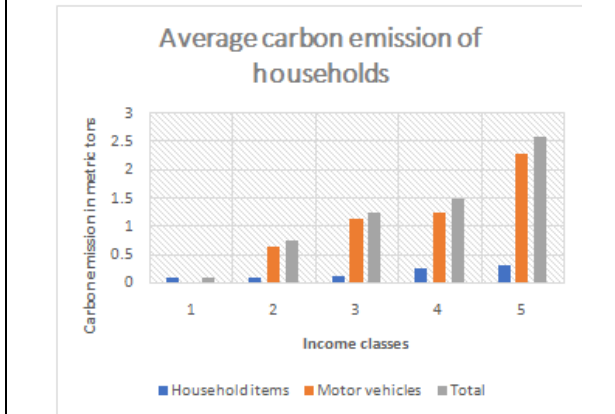


Figure 3: Chart showing average overall carbon footprint from the households.



Figure 4: Carbon footprint of the surveyed





Analyzing Everyday Psychological Boredom in the Aspects of Existentialism

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ABSTRACT

This article explores how people suffer from Everyday psychological Boredom in their day-to-day lives. How do the authors and psychological theory of boredom give a remedy for boredom? We all face boredom in everyday life, like work, academics, emptiness, emotional disturbance, and the acceptance of problems. People can recover from boredom and change their minds, focusing on their careers and daily activities. When we feel down in the work and upset at work, it is also called boredom in life. Sometimes, people think alone and need more social contact, which makes their lives boring. Some people are always isolated from others.

Keywords: Everyday Boredom, Existentialism, Work Boredom, Academic Boredom, Emptiness, Psychological Boredom

INTRODUCTION

Boredom means one who needs more interest in their day-to-day lifestyles. It is not only physical but also mental healthiness. When people get bored with their surroundings or their activities, they will suddenly become frustrated, confused, anxious, etc.; boredom factors can cause boredom. There was Monotony, lack of challenge, stimulation, and lack of interest. The effects of boredom were often temporary, and it was an individual behavior. The common effects of boredom were Decreased productivity, Negative Emotions, risk-taking Behaviour, and impact on mental health. We always cope with boredom by engaging in our thoughts, doing new activities, practicing mindfulness,



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and making social connections. Boredom was a common experience that arose from a lack of mental stimulation or engagement with our surroundings.

LITERARY REVIEW

Numerous writers have confirmed the fact that boredom is the most awful emotion. They view boredom as distress in which one's existence becomes meaningless and purposeless. In that case, boredom is "an affective consequence of effortful maintenance of attention to a particular stimulus" (Leary et al. 1968). It will be felt whenever the person finds it difficult to focus for any reason. M Martin et al. (2002) discussed several common experiences of boredom. Those feelings include being constrained, restless, lethargic, however guilty, and in certain situations, depression. People who were bored at work experienced a sense of being entrapped. They felt more in control of their life at home compared to work. Individuals who experienced boredom at home also reported feelings of restlessness. They could not focus on a single activity or rest, so they looked for other options. Despite having the freedom to do as they pleased, some felt bad because they failed to make the best use of their time, and some experienced severe depression. According to Bench and Lench (2013), boredom leads one to attain a new goal. A desire for change is motivated by boredom, which leads one to do certain actions that are different from the current state. While boredom is considered unpleasant and negative, they stated that boredom will encourage people to seek new goals, though it involves situations that might cause discomfort.

DISCUSSION**Theory of Existentialism**

Boredom gives people the freedom to do what they want to do next. Sartre says, "...it is we, ourselves, who decide who we are to be" (Sartre 34). One could say human freedom is the core concept of Sartre's existentialism. In his play *The Flies* (1984), he discusses the importance and journey of getting freedom, a key existentialist concept. "Sartre has the idea that people can create their world through freedom. Sartre's opinion is that people are free to make a choice and to act according to that choice" (Mart 52). The protagonist, Orestes, is free since he left his past behind and only thought about his future, whereas his sister, Electra, feels about her past and seeks revenge so she cannot look ahead and is not free. Being an existentialist, Sartre discusses many themes in his writings, such as absurdity. Although life is meaningless and absurd, humans must make it meaningful by themselves. Another is alienation, an effect of feeling like a stranger in the world and themselves.

Albert Camus was a philosopher, author, and journalist who created thoughts about absurdism. According to Albert, existentialism theory was a search for a meaningless and empty world. It also emphasizes individual freedom and choice. His philosophy was when people suffer to face a problem, they make their own decisions, feeling absurd in the lives. So, the people conclude their lives by Faith, Suicide, and Absurdity. Existentialism greatly impacted society because the public always watched others' problems and found mistakes in other lives. It also makes people feel so alone and disturbs their personal lives.

Psychological Boredom in Life

The world is filled with the laughter of those innocent people, which makes this earth even more possible for a new beginning. When one among them is missed or absent, they feel lonely. The moments that make the joyful will no longer be seen. All those moments that were saved in pictures are still soulful. Boredom is found in one when all the surrounding things feel numb and meaningless. They search for a new world inside themselves. Their moments with family, friends, children, and so on will be absent. They start to feel loneliness, depression, and anxiety, which are all the causes of boredom in their life. Boredom is found in the workplace, school, college academics, and life's emptiness. The lack of interest in certain areas of occupation and academics caused all these. "Boredom is a state of mind characterized by a lack of interest, stimulation, or challenge. It is a subjective experience that can manifest in various ways, including restlessness, apathy, and disinterest." (Ndetei et al. 2).



**Vijayalakshmi and Devibala****Work boredom**

Humans live their lives once and have yet to complete anything. Their desires lead them to all sorts of complications. People need to catch up on what they are doing every day. As they are trained and shaped by continuously working day after day, they don't know anything other than waking up, eating, and starting to work on their occupation. They are completely on their schedule on working and leading their life. After work, they don't have any other enjoyment. The fun was missed after having a scheduled workplace and environment. They sit in front of a computer all day and do their work, which they regularly do. The fun in the outside world is hidden and confined within a small screen. This causes them boredom when they do not think of anything else than work. The boredom while doing the same process leads them to laziness in mind, physical and mental exhaustion, and especially to exist in this world as a human being but not for a soulful life. Boredom at work is inevitable because of their way of living in the occupation. "Furthermore, boredom is an activity-related emotion that fades away when one is no longer involved in the boredom-evoking situation. A daily diary design is, therefore, appropriate, as it allows us to examine boredom close to the time that it is experienced (i.e., while working)" (Hooff and Hoofft 251). All they have to do is stay still, work, and avoid boredom during working hours. Companies have started introducing small cafes inside the workplace to make them more active and energized.

Academic bore

Homosapiens rule the worldviews. The next generation is carried out with the young teenagers after the parent's generation. These teenagers are energetic and excited to know all the world's best adventures except for studies. They find it to be difficult yet more boring. They prefer to be instructed where the education place is all about instruction and full of rules and regulations. "Boredom occurs regularly at work and can have negative consequences" (van Hooff and van Hoofft133). Young minds are searching for interesting life events that are not found in the book. This makes them feel bored. They are bored due to the syllabus's scheduled pattern. They do not find it interesting. Nowadays, kids are more educated by society and the environment. They want something new knowledge to add to their minds. It is in positive aspects also. "In particular, boredom is intimately linked to the project and promises of modernity and its associated effects on time, from factory industrialization to contemporary work platforms." (Noury et al. 791). So, they find it boring when all these syllabuses are already planned, and they are not ready to accept new forms. They do not want to sit still in a fixed place and cannot look around the world. They find it boring to be in a safe environment for a year. The classes felt boring due to their fixed points, which were not for the students' taste. The early waking makes them exhausted and rebelled, making them tired and lazy. This makes them feel bored, making them mentally absent during class hours. They often sit and watch what happens outside the classroom. Like in Beckett's "Waiting for Godot", the characters Estragon and Vladimir. "Everything is repetitive and going on cyclically. Life is meaningless as a bubble. All these issues emerged after the misshape of world wars and the consequences of that brutality. The existence of human beings and God was in question." (Fatima et al. 137).

Emptiness in Life

Life is beautiful when your soul finds its place. The environment decides most of your activeness in mind. If it is not found, you feel empty when nothing seems interesting. You are not ready to do a daily routine and feel tired and lazy. Feeling lazy makes one feel lethargic about one's life, work, and existence. Being sluggish is one of the common emotions felt by bored people. People often lose interest in everything, even their favorite activity, as they feel bored. This lack of interest makes them feel empty and question their existence. Here, their life becomes pointless. Though they are free in this world, they feel trapped within themselves.

CONCLUSION

Boredom is not a terminal disease that one cannot cure. People can overcome boredom by accepting and moving on from the current situations. In the case of workplace boredom, the employees can be given more control over their work instead of controlling them and constraining them at a particular place. They can provide breaks at regular intervals so they feel supported with their work and energized.



**REFERENCES**

1. Bench, Shane, and Heather Lench. "On The Function of Boredom." *Behavioral Sciences*, vol. 3, no. 3, Aug. 2013, pp. 459–472, DOI: 10.3390/bs3030459.
2. Fatima, Syeda Ujala, et al. "Waiting for Godot As A Drama Of Existence," *Journal of English Language and Literature*, vol.5, No.1, pp.137-142, ISSN: 2349-9753.
3. Hooff, Madelon L. M. van, and Edwin A. J. van Hooff. "Boredom at Work: Towards a Dynamic Spillover Model of Need Satisfaction, Work Motivation, and Work-related Boredom." *European Journal of Work and Organizational Psychology*, vol. 26, no. 1, Oct. 2016, pp. 133–48. DOI: 10.1080/1359432x.2016.1241769.
4. Hooff, Madelyn L. M. van, and Hooff, Edwin A. J. van, "Dealing with daily boredom at work: does self-control explain who engages in distractive behavior or job crafting as a coping mechanism?", *An International Journal of Work, Health & Organisations*, vol. 37, no. 2, pp. 248-268, <https://doi.org/10.1080/02678373.2022.2129515>.
5. Leary, Mark R., et al. "Boredom in Interpersonal Encounters: Antecedents and Social Implications." *Journal of Personality and Social Psychology*, vol. 51, no. 5, Nov. 1986, pp. 968–975, <https://doi.org/10.1037/0022-3514.51.5.968>.
6. Mart, Cagri Tugrul. "Existentialism in two plays of Jean-Paul Sartre." *Journal of English and Literature*, vol. 3, no. 3, March 2012, pp. 50-54, DOI:10.5897/IJEL11.042.
7. Martin, Marion, et al. "The Phenomenon of Boredom." *Qualitative Research in Psychology*, vol. 3, no. 3, Jan. 2006, pp. 193–211, <https://doi.org/10.1191/1478088706qrp066oa>.
8. Ndetei, David M., et al. "Boredom–understanding the Emotion and Its Impact on Our Lives: An African Perspective." *Frontiers in Sociology*, vol. 8, June 2023. DOI: 10.3389/fsoc.2023.1213190.
9. Noury, Lucie, et al. "In Praise of Boredom at Work." *Organization*, vol. 29, no. 5, Sept. 2022, pp. 791–805. DOI: 10.1177/13505084221119267.
10. Sartre, Jean-Paul. *Existentialism is a Humanism*. London: Yale University Press. 2007.





Advancements in Diagnosing and Monitoring Knee Osteoarthritis through Intelligent Sensor Technologies

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ABSTRACT

Osteoarthritis (OA) is a deteriorating joint illness primarily disturbing the knee. It arises from the progressive deterioration of the cushioning cartilage that surrounds the tips of the bones in the knee joint. Due to deterioration of cartilage, the bones may rub against each other, leading to symptoms such as pain, stiffness, and decreased mobility. These symptoms collectively contribute to the clinical profile of knee osteoarthritis, highlighting the importance of early detection and appropriate management strategies for affected individuals. Maintaining a healthy weight reduces stress on the knee joints. Avoiding activities that put excessive strain on the knees and using assistive devices when needed. The study involves utilization of deep convolutional neural network (CNN) with a DenseNet-121 base model, The proposed layers have been refined to effectively classify and detect Knee Osteoarthritis (KOA) Grades. In addition to this model, other deep learning algorithms, namely VGG16, ResNet50, and DenseNet-121, are employed for comparative analysis. Wearable sensors provide a convenient way to



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continuously monitor knee angles during daily activities, offering a more comprehensive understanding of joint dynamics in real-life scenarios. The study evaluates the performance and monitoring of the proposed CNN architecture compared to established deep learning models for KOA classification and detection.

Keywords: Knee Osteoarthritis, Degenerative Joint Disease, Arthritis, Orthopedic Conditions, Deep Learning.

INTRODUCTION

Knee osteoarthritis stands as a key public health concern, disturbing lots of persons globally. The degenerative changes in the knee joint associated with OA provide significant challenges for healthcare systems and individuals alike. Pain is a prominent feature, with individuals experiencing discomfort in the knee joint, especially during or after engaging in activities. Stiffness is another characteristic, often observed in the knee following periods of inactivity. Swelling or inflammation within the knee joint contributes to the overall manifestation of the condition. Reduced range of motion is a key indicator, as individuals may encounter difficulty in bending or straightening the knee, signifying limitations in mobility. Joint crepitus, marked by a grating or crackling sensation during knee movement, is a notable aspect often associated with the friction of joint surfaces. Conventional diagnosis techniques frequently depend on subjective assessments, and monitoring disease progression necessitates frequent clinical visits. This creates an imperative for the integration of intelligent sensor technologies to provide continuous, objective, realtime data for enhanced understanding and management of knee OA. The motivation behind this research lies in the limitations of current knee osteoarthritis diagnostic and monitoring approaches. Existing methodologies often lack the sensitivity to detect subtle changes in joint health, and the intermittent nature of clinical assessments hinders the timely intervention required for effective disease management. Intelligent sensor technologies, such as wearable devices and advanced imaging modalities, present an opportunity to bridge these gaps, offering continuous and quantifiable insights into the dynamic nature of knee OA. This paper aims to explore the potential of intelligent sensor technologies in revolutionizing the landscape of knee osteoarthritis diagnostics and monitoring. We delve into the key challenges associated with traditional methods and present a detailed analysis of the capabilities and limitations of emerging sensor technologies.

MATERIALS AND METHODS

[1]The BAPNET model achieved a mean square error of 1.15 on 70 preterm infants, demonstrating its ability to estimate brain maturity. The study suggests BAPNET could be a benchmark for premature baby brain development, but calls for further research to improve performance and scalability.[2] The paper discusses the use of AI technologies for diagnosing breast cancer, highlighting privacy risks in centralized learning environments. It proposes a federated learning approach, incorporating transfer learning, synthetic minority oversampling technique, and FeAvg-CNN + MobileNet for security. Experimental results show the FL approach improves classification performance, making it a viable option for AI healthcare applications. The prediction of tumors and the accurate identification and localization of lesions are expected to enhance patient survival.[3] The study introduces a Deep Transfer Ensemble (DTE)architecture-neutral and computationally efficient, for detecting Alzheimer's disorder through MRI scans.DTE achieved high accuracy rates of 99.05%, outperforming other models, and outperformed other deep models on independent datasets. [4]This study introduces a Dual Attention Transformer model for multi-label image categorization, outperforming existing models in classification by learning spatial and channel correlations from multi-label images.[5] It proposes a new deep learning model by utilizing the K-Nearest Neighbor method and a genetic algorithm, attaining high detection accuracy of over 95%, precision of 98%, and low loss of 0.12. The model's superior detection ability is highlighted for proper patient treatment.[6] The author introduces a



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new automatic image annotation model called Auxiliary classifier-GAN (ACGAN) to improve image annotation and classification performance. The model uses a discriminator to predict image class, stabilizing the training stage and generating high-quality images. Transfer learning enhances classification performance. The model outperforms in multiple evaluation metrics, demonstrating the potential of integrating GANs and transfer learning in AIA models. [7] The DNA-Net outperforms other advanced techniques in terms of intersection, union, false-alarm rate, and likelihood of detection in small targets. [8] The study describes a Transfer Learning method that uses retinal fundus images to diagnose diabetic retinopathy (DR). It uses networks such as ShuffleNet and ResNet-18 to improve detection and classification. The authors use Adaptive Differential Evolution for feature selection and parameter tuning. The method outperforms conventional models and is comparable to existing research. The optimal configuration achieves 82% accuracy for APTOS 5-class DR grading and 96% for APTOS 2-class grading. [9] The research article discusses the challenges of training deep spiking neural networks (SNNs) with large labelled datasets. It proposes a transfer learning framework based on domain invariance representation, focusing on the application of centered kernel alignment (CKA) as a method of measuring domain distance. According to experimental data, the framework improves feature transferability between layers, which advances training efficiency and advances the study of transfer learning in SNNs. [10] The author describes a multi-class method for classifying plant diseases that have been trained beforehand. With a high accuracy of 98.71%, the EfficientNetB3-adaptive augmented deep learning model performed better than other models and traditional techniques.

This study shows how the EfficientNetB3-AADL model may be used to accurately and quickly diagnose diseases in agricultural systems, and it suggests that augmented deep learning and transfer learning methods can improve the model's functionality. [11] The paper presents a novel method of knowledge transfer known as teacher-student learning and looks into the difficulties of training deep learning models in low-data contexts. Inspired by activation attention transfer in computer vision models, the authors investigate various configurations inside the framework using typical transfer learning techniques. The study shows the potential of this approach in improving diagnostic model performance, especially in limited data environments, and suggests its implications for healthcare accessibility and affordability. [12] The paper discusses automating manual histopathology image analysis in cancer diagnosis. The algorithms extract extensive histopathological features for best outcomes, based on ensemble learning and intra-domain transfer learning. Tested on public histopathology datasets, the models achieved better accuracy, enhancing patient survival rates and improving early cancer detection. The results suggest these models could reduce workload and mortality rates. [13] Using deep learning approaches, the study achieves good accuracy, sensitivity, precision, specificity, and F1-score on both small and big datasets in the classification of early brain cancers from MRI data. [14] The high death rate among women and the effects of breast cancer on the world are covered in the study. It proposes an intelligent breast cancer image analysis system using ensemble stacking machine learning models and transfer learning, outperforming current techniques. [15] It introduces a Transformer's multi-level self-attention mechanism and uses practical CXR image data augmentation. The method's effectiveness is demonstrated on a COVID-19 recognition task, emphasizing the importance of chest imaging in diagnosing and predicting respiratory status. The paper underscores the need for more interpretable and efficient deep learning-based frameworks. [16]

The article explores the use of transfer learning-based deep learning methods and traditional classifiers for brain tumor detection, revealing a 99.39% accuracy rate for the best model. [17] The research presents a novel framework for identifying picture orientation using transfer learning methods. It detects four picture orientation probabilities and extracts features making use of a convolutional neural network model that has been trained, outperforming high-tech methods. [18] With the intention of distinguish between osteoporotic and normal knee states, even in the presence of slight fluctuations in the data, we provide KONet, a robust detection method that makes use of a weighted ensemble approach. We tested several cutting-edge CNN-based models employing transfer learning in order to verify the architectural decisions made in the ensemble approach. VGG-19 architecture, well-known for its efficiency and ease of use in image categorization applications. With an input layer designed for images of fixed size (224x224 pixels), the network comprises 16 convolutional layers organized into five blocks, each tailed in max-pooling layer for down sampling. Following the convolutional blocks, the architecture consists of three fully connected layers using 3x3 receptive fields and activation functions ReLU. Fully connected layer acts as an output layer, has neurons that match



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the classes of the job. ReLU activation function is applied throughout, except for the SoftMax activation in the output layer. Dropout is implemented in the fully connected layers during training to mitigate overfitting. ResNet50 is a widely used CNN model that effectively addresses the degradation issues associated with increasing network layers. It incorporates skip connections, allowing the original input signal to bypass layers and reach subsequent ones. Convolutional layers, batch normalization, pooling, and ReLU activation are the model's residual blocks, which work to prevent gradient degradation and overfitting. In the evaluation of a hybrid model combining ResNet50 with the ImageNet model for diagnosing breast cancer, training results illustrate an increase in validation accuracy over time and a decrease in training loss over epochs. However, validation accuracy remains consistently low, indicating the need for performance enhancement techniques. DenseNet is a well-known architecture specifically designed for image classification tasks, with DenseNet121 being a variant featuring 121 layers. Transition layers, classifiers, and dense blocks constitute the three primary parts of the model. The key components of the feature map are the dense blocks, which are composed of up of connected convolutional layers that take input from each layer before it and preserve uniform feature map size. This intricate connectivity helps preserve information across the network, addressing the vanishing gradient issue and enhancing learning capability. Using a combination of pooling and convolutional layers, the transition layer makes down sampling easier. Last but not least, the classifier, which provides anticipated results, comprises fully connected layer with SoftMax activation function after a global pooling layer. DenseNet's architecture promotes parameter efficiency and improved model accuracy through its unique connectivity approach.

Fine-tuning

Fine-tuning in Convolutional Neural Networks (CNNs) involves adapting a pre-trained model to a fresh task or dataset. Typically, previously trained CNN model, like VGG, ResNet, or Efficient Net. The process begins with preparing a task-specific dataset, and adjustments are made to the model architecture, particularly modifying or replacing the final layers to suit the new task's class requirements. Optionally, certain layers may be frozen to retain knowledge from the original task, while others are unfrozen for task-specific learning. After that, the model is adjusted on the fresh dataset, which enables it to pick up task-specific characteristics while holding onto the overall knowledge it learned during pre-training. This method allows for the utilization of pre-trained knowledge to enhance performance on the target task and is especially helpful when the new dataset is tiny or drastically different from the original.

Transfer Learning

Knowledge is transferred as part of transfer learning to a new model that is created for a particular purpose and may have a smaller dataset. The process involves reusing the pre-trained model's learned parameters, possibly adjusting the architecture, and fine-tuning the model on the target task's dataset. Transfer learning is particularly advantageous when the new task lacks sufficient data for training a model from scratch or when tasks share underlying features. By capitalizing on the pre-trained model's understanding of generic features, CNN transfer learning facilitates the efficient development of models for diverse tasks, ranging from image classification to object detection and beyond.

Attention Mechanism

Convolutional Neural Networks (CNNs) with attention mechanisms represent an advancement in deep learning by incorporating selective attention on precise regions of data. The attention mechanism enables to dynamically weigh different regions of the input, allowing it to prioritize relevant information while downplaying less critical regions. This mechanism is particularly beneficial for tasks like image recognition, where certain areas may contain more crucial features than others. CNNs with attention improve accuracy and interpretability by strengthening model's capacity to identify complex patterns and connections in input. By adaptively attending to salient features, the attention mechanism contributes to the network's ability to discern intricate details and patterns, making it a powerful tool in various tasks related to natural language processing, object detection, and image classification are among the applications.



**Ranjani and Thara****Monitoring**

In order to continuously monitor joint kinematics in ambulatory settings, a wearable device that prioritizes affordability, power economy, and dependability is introduced in this study[19]. The knee flexion/extension angles when walking at various speeds are measured by the device using a retractable string sensor.[20] The proposed device has the potential to aid clinicians in monitoring joint recovery and developing personalized rehabilitation programs. Additionally, another study investigates age-related changes in knee acoustic emission (AE) using 51 participants in two age groups (18-35 and 50-75) cycling at different cadences. While some potential for age group differentiation was observed with low-frequency sensors and hit modes, weak correlations were found between age and specific AE parameters. The findings suggest avenues for further research and potential applications in clinical practice. The pilot study demonstrates wearable devices accurately classify pre-radiographic knee OA from healthy knees, potentially improving access to evaluation tools, reducing costs, and potentially improving early disease intervention. Sensors measuring knee joint range of motion can track flexion and extension angles, enabling personalized management of Knee Osteoarthritis [21]. Collaborating with healthcare professionals and patients is crucial for system effectiveness and acceptance, ensuring improved patient outcomes. Monitoring flexion and extension angles helps in evaluating the knee's ROM (Range of Motion), which tends to decrease in individuals with Knee OA. Restricted ROM is often an early sign of OA. Sensors tracking flexion angles during specific activities can help correlate joint angles with pain levels. This information aids in understanding how joint movement contributes to pain and discomfort [22]. When implementing interventions like physiotherapy or exercise programs, tracking joint angles helps assess the effectiveness of treatments. Positive changes may indicate improved joint function and reduced symptoms. Monitoring angles during activities like squatting, rising from a chair, or climbing stairs helps assess how the knee joint is loaded dynamically. Excessive loading can contribute to OA progression [23].

Sensors provide objective and quantitative data on knee joint movement, angles, and biomechanics, reducing reliance on subjective assessments. Wearable sensors enable continuous monitoring of knee parameters during various activities in real-life settings, offering a more comprehensive view of daily function. Sensors can detect subtle changes in joint movement and loading patterns, allowing for early detection of deviations and potential signs of Knee Osteoarthritis. Sensor data could be utilized to construct tailored treatment tactics to individual's needs of knee joint dynamics and functional limitations. Wearable sensors facilitate remote monitoring, enabling healthcare professionals to assess patients' conditions without the need for frequent in-person visits. Patients actively involved in monitoring their knee joint parameters may feel more engaged in their care, leading to increased adherence to treatment plans [24]. Sensor data, when integrated with clinical assessments and imaging, provides a more comprehensive understanding of the patient's condition, aiding in clinical decision-making. Continuous monitoring generates large amounts of data, requiring sophisticated analysis methods and potentially overwhelming healthcare providers.

RESULTS AND DISCUSSION

Advancements in diagnosing and monitoring knee osteoarthritis (OA) through intelligent sensor technologies are expected to bring about early detection, objective assessment of disease progression, and personalized treatment plans. Remote monitoring and telemedicine applications may enhance accessibility to healthcare, empowering patients to actively manage their condition. The integration of sensor data with wearable devices and its use as objective outcome measures in clinical trials can contribute to cost-effective healthcare and improved insights into knee OA. Intelligent sensors can enable early detection of subtle changes in knee joint mechanics and function. Enhanced diagnostic accuracy through continuous monitoring, allowing for the identification of pre-symptomatic stages of knee OA. Quantitative data from sensors provide objective measures of joint function and disease progression. Telemedicine applications utilize sensor data for real-time consultations, enhancing accessibility to healthcare for individuals with knee OA, enabling personalized treatment plans and interventions. Intelligent sensors provide detailed biomechanical and physiological data, enabling the creation of personalized treatment plans. Healthcare professionals can tailor interventions based on individual patient needs and responses to therapy.



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Continuous monitoring fosters patient engagement and awareness of their condition. Patients can actively participate in their care by receiving real-time feedback and adjusting their activities accordingly to manage symptoms. Early intervention and proactive management facilitated by intelligent sensors can potentially reduce long-term healthcare costs associated with knee OA. Integration with wearable devices, such as smart knee braces or joint sleeves, allows for unobtrusive and continuous monitoring during daily activities. Large-scale data from diverse populations can offer valuable insights into the epidemiology, progression, and treatment outcomes of knee OA. Ongoing advancements in sensor technologies will likely lead to continuous improvement in the accuracy, sensitivity, and usability of devices for knee OA monitoring. Early detection through intelligent sensors allows for timely intervention, potentially preventing or slowing down the progression of knee OA. By identifying pre-symptomatic stages, healthcare providers can implement targeted strategies to mitigate the impact of the disease. Customized treatment plans based on detailed biomechanical and physiological data enhance patient centered care. Remote monitoring reduces the burden on healthcare facilities, making healthcare more accessible for individuals with knee OA. Telemedicine applications leveraging sensor data offer real-time consultations, improving patient-doctor communication and reducing the need for frequent in-person visits. The use of sensor data as objective outcome measures in clinical trials enhances the validity and reliability of research on knee OA treatments. Researchers can gather more accurate data, leading to better-informed decisions regarding the effectiveness of interventions. Cost-effective healthcare is a crucial benefit, as early intervention and proactive management can potentially reduce the long-term financial burden associated with knee OA. The integration of sensor technologies may result in more efficient resource utilization and healthcare spending.

CONCLUSION

The integration of intelligent sensor technologies in diagnosing and monitoring knee osteoarthritis marks a significant advancement in personalized healthcare. These sensors enable objective, real-time data collection and offer opportunities for remote monitoring, alleviating healthcare system burdens and enhancing patient outcomes. Combining machine learning and artificial intelligence further improves diagnostic accuracy and predicts disease progression. Despite these achievements, challenges like standardization, interoperability, and ethical considerations persist. Addressing these issues in future research is crucial, along with expanding the use of intelligent sensors to diverse patient groups. Interdisciplinary collaboration among clinicians, engineers, and data scientists is essential for developing robust and widely accessible solutions. Looking forward, the ongoing evolution of sensor technologies holds the potential to revolutionize knee osteoarthritis management. The journey towards a more intelligent and connected healthcare system is underway, with intelligent sensor technologies playing a pivotal role in shaping the future of knee osteoarthritis diagnosis and monitoring.

REFERENCES

1. Tang, J., Yang, P., Xie, B., Wei, C., Hu, L., Wang, S., Jiang, Y., Li, R., Zhou, H., Xu, H., Wan, Q., Han, J., Zhao, D., & Lu, L. (2023). A Deep Learning-Based Brain Age Prediction Model for Preterm Infants via Neonatal MRI. *IEEE Access*, 11, 68994–69004. <https://doi.org/10.1109/ACCESS.2023.3291810>.
2. Tan, Y. N., Tinh, V. P., Lam, P. D., Nam, N. H., & Khoa, T. A. (2023). A Transfer Learning Approach to Breast Cancer Classification in a Federated Learning Framework. *IEEE Access*, 11, 27462–27476. <https://doi.org/10.1109/ACCESS.2023.3257562>
3. Tanveer, M., Rashid, A. H., Ganaie, M. A., Reza, M., Razzak, I., & Hua, K. L. (2022). Classification of Alzheimer's Disease Using Ensemble of Deep Neural Networks Trained Through Transfer Learning. *IEEE Journal of Biomedical and Health Informatics*, 26(4), 1453–1463. <https://doi.org/10.1109/JBHI.2021.3083274>.
4. Zhou, W., Zheng, Z., Su, T., & Hu, H. (2023). DATran: Dual Attention Transformer for Multi-Label Image Classification. *IEEE Transactions on Circuits and Systems for Video Technology*. <https://doi.org/10.1109/TCSVT.2023.3284812>.





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5. Abdullah, S. M., Abbas, T., Bashir, M. H., Khaja, I. A., Ahmad, M., Soliman, N. F., & El-Shafai, W. (2023). Deep Transfer Learning Based Parkinson's Disease Detection Using Optimized Feature Selection. *IEEE Access*, 11, 3511–3524. <https://doi.org/10.1109/ACCESS.2023.3233969>
6. Alshehri, A., Taileb, M., & Alotaibi, R. (2022). DeepAIA: An Automatic Image Annotation Model Based on Generative Adversarial Networks and Transfer Learning. *IEEE Access*, 10, 38437–38445. <https://doi.org/10.1109/ACCESS.2022.3165077>
7. Li, B., Xiao, C., Wang, L., Wang, Y., Lin, Z., Li, M., An, W., & Guo, Y. (2023). Dense Nested Attention Network for Infrared Small Target Detection. *IEEE Transactions on Image Processing*, 32, 1745–1758. <https://doi.org/10.1109/TIP.2022.3199107>
8. Wong, W. K., Juwono, F. H., & Apriono, C. (2023). Diabetic Retinopathy Detection and Grading: A Transfer Learning Approach Using Simultaneous Parameter Optimization and Feature-Weighted ECOC Ensemble. *IEEE Access*, 11, 83004–83016. <https://doi.org/10.1109/access.2023.3301618>
9. Zhan, Q., Liu, G., Xie, X., Sun, G., & Tang, H. (2022). Effective Transfer Learning Algorithm in Spiking Neural Networks. *IEEE Transactions on Cybernetics*, 52(12), 13323–13335. <https://doi.org/10.1109/TCYB.2021.3079097>
10. Adnan, F., Awan, M. J., Mahmoud, A., Nobanee, H., Yasin, A., & Zain, A. M. (2023). EfficientNetB3-Adaptive Augmented Deep Learning (AADL) for Multi-Class Plant Disease Classification. *IEEE Access*, 11, 85426–85440. <https://doi.org/10.1109/ACCESS.2023.3303131>
11. Akbarian, S., Seyyed-Kalantari, L., Khalvati, F., & Dolatabadi, E. (2023). Evaluating Knowledge Transfer in the Neural Network for Medical Images. *IEEE Access*, 11, 85812–85821. <https://doi.org/10.1109/ACCESS.2023.3283216>
12. MING PING YONG¹, YAN CHAI HUM. (2023). Histopathological Cancer Detection Using Intra-Domain Transfer Learning and Ensemble Learning. Digital Object Identifier 10.1109/ACCESS.2023.3343465.
13. Asif, S., Yi, W., Ain, Q. U., Hou, J., Yi, T., & Si, J. (2022). Improving Effectiveness of Different Deep Transfer Learning-Based Models for Detecting Brain Tumors From MR Images. *IEEE Access*, 10, 34716–34730. <https://doi.org/10.1109/ACCESS.2022.3153306>
14. Aziz, S., Munir, K., Raza, A., Almutairi, M. S., & Nawaz, S. (2023). IVNet: Transfer Learning Based Diagnosis of Breast Cancer Grading Using Histopathological Images of Infected Cells. *IEEE Access*, 11, 127880–127894. <https://doi.org/10.1109/ACCESS.2023.3332541>
15. Azour, F., & Boukerche, A. (2023). An Efficient Transfer and Ensemble Learning Based Computer Aided Breast Abnormality Diagnosis System. *IEEE Access*, 11, 21199–21209. <https://doi.org/10.1109/access.2022.3192857>
16. Shah, H. A., Saeed, F., Yun, S., Park, J. H., Paul, A., & Kang, J. M. (2022). A Robust Approach for Brain Tumor Detection in Magnetic Resonance Images Using Finetuned EfficientNet. *IEEE Access*, 10, 65426–65438. <https://doi.org/10.1109/ACCESS.2022.3184113>
17. Benali Amjoud, A., & Amrouch, M. (2022). Transfer Learning for Detecting Image Orientation Using Convolutional Neural Networks and Logistic Regression. *SSRN Electronic Journal*. <https://doi.org/10.2139/ssrn.4196889>
18. Rasool, M. J. A., Ahmed, S., Sabina, U., & Whangbo, T. K. (2023). KONet: Towards a Weighted Ensemble Learning Model for Knee Osteoporosis Classification. *IEEE Access*. <https://doi.org/10.1109/ACCESS.2023.3348817>
19. Oubre, B., Daneault, J. F., Boyer, K., Kim, J. H., Jasim, M., Bonato, P., & Lee, S. I. (2020, December). A Simple Low-Cost Wearable Sensor for Long-Term Ambulatory Monitoring of Knee Joint Kinematics. *IEEE Transactions on Biomedical Engineering*, 67(12), 3483–3490. <https://doi.org/10.1109/tbme.2020.2988438>
20. Tsujii, A., Nakamura, N., & Horibe, S. (2017, December). Age-related changes in the knee meniscus. *The Knee*, 24(6), 1262–1270. <https://doi.org/10.1016/j.knee.2017.08.001>
21. Richardson, K. L., Teague, C. N., Mabrouk, S., Nevius, B. N., Ozmen, G. C., Graham, R. S., Zachs, D. P., Tuma, A., Peterson, E. J., Lim, H. H., & Inan, O. T. (2022, December). Quantifying Rheumatoid Arthritis Disease Activity Using a Multimodal Sensing Knee Brace. *IEEE Transactions on Biomedical Engineering*, 69(12), 3772–3783. <https://doi.org/10.1109/tbme.2022.3177074>





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22. Nichols, C. J., Özmen, G. C., Richardson, K., Inan, O. T., & Ewart, D. (2023, December 1). Classifying Pre-Radiographic Osteoarthritis of the Knee Using Wearable Acoustics Sensing at the Point of Care. *IEEE Sensors Journal*, 23(23), 29619–29629. <https://doi.org/10.1109/jsen.2023.3325153>
23. Critcher, S., Parmelee, P., & Freeborn, T. J. (2023). Localized Multi-Site Knee Bioimpedance as a Predictor for Knee Osteoarthritis Associated Pain Within Older Adults During Free-Living. *IEEE Open Journal of Engineering in Medicine and Biology*, 4, 1–10. <https://doi.org/10.1109/ojemb.2023.3256181>
24. Oubre, B., Lane, S., Holmes, S., Boyer, K., & Lee, S. I. (2022, April). Estimating Ground Reaction Force and Center of Pressure Using Low-Cost Wearable Devices. *IEEE Transactions on Biomedical Engineering*, 69(4), 1461–1468. <https://doi.org/10.1109/tbme.2021.3120346>

Table 1: Feature Comparison of different CNN Architectures.

Feature	VGG-19	ResNet-50	DenseNet-121
Architecture Type	Plain (No skip connections)	Residual (Skip connections)	Densely connected (Skip connections)
Depth	19 layers	50 layers	121 layers
Convolution Layers	16 convolutional layers	Convolutional layers in residual blocks	Convolutional layers in dense blocks
Pooling Layers	5 max-pooling layers	Occasional down sampling	Transition layers (down sampling)
Skip Connections	No	Yes (Identity and 1x1 convolutions)	Yes (Concatenation of feature maps)
Global Pooling (AVG)	No	Yes	Yes
FCL	3 (4096 neurons each)	1 (Adaptable to task)	1 (Adaptable to task)
Activation Function	ReLU	ReLU	ReLU
Batch Normalization	Yes	Yes (Applied within residual blocks)	Yes (Applied within dense blocks)
Dropout	Yes (Applied in fully connected layers)	Yes (Applied in fully connected layer)	No (Dense connections act as regularization)
Number of Parameters	Approximately 143.67 million	Approximately 25.56 million	Approximately 8.06 million
Advantages	Simplicity, Easy to understand	Mitigates vanishing gradient problem	Promotes feature reuse, reduces redundancy
Disadvantages	Prone to overfitting due to many parameters	Complexity due to skip connections	Higher memory consumption due to dense connectivity

Table 2. Performance Evaluation

Classifier	Performance Evaluation Methods		
	Accuracy %	Precision%	Recall %
VGG-19	92.63	92.21	92.51
ResNet - 50	93.33	93.21	93.33
DenseNet-121	95.51	94.79	95.12
Proposed model	97.13	97.01	97.13





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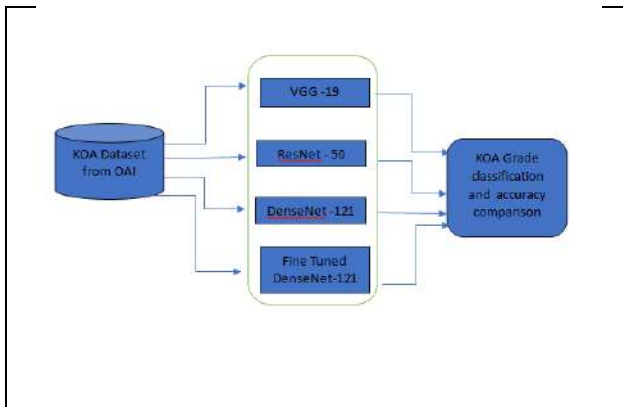


Fig 1: Three pre-trained ImageNet network predictions and Fine-tuned Network Prediction

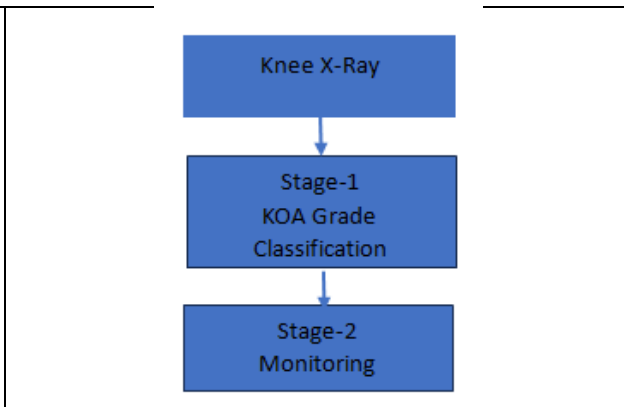


Fig 2: Two staged Architecture

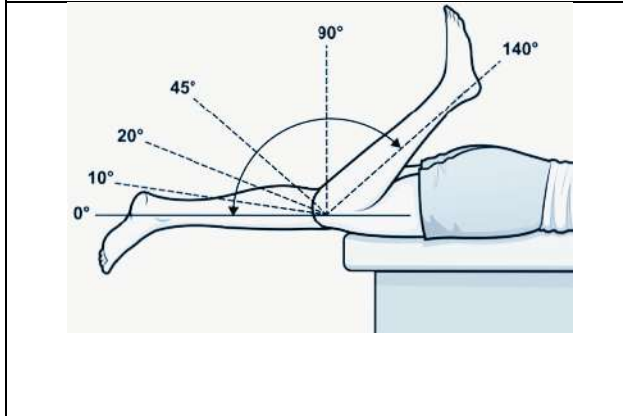


Fig 3: Knee Flexion Angles



Fig 4: Training Loss and Accuracy

	Normal	Doubtful	Mild	Moderate	Severe
Normal	71	29	6	3	1
Doubtful	12	16	9	4	5
Mild	9	9	16	11	9
Moderate	0	1	3	26	2
Severe	1	8	4	5	18

predicted label

Fig 5: Multi Class Confusion Matrix

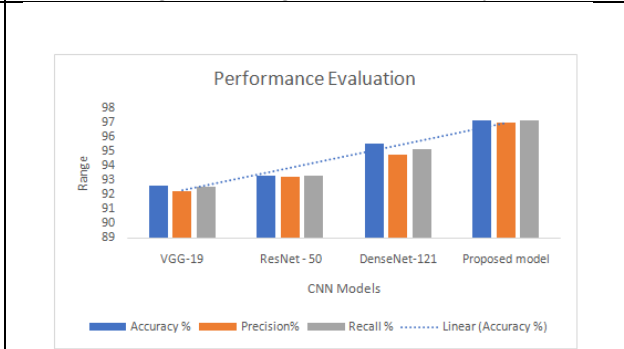


Fig 6: Performance Evaluation





Management of Bronchial Asthma in Ayurveda through Vamana (Therapeutic emesis) along with Oral Ayurvedic Medication: A Case Study

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ABSTRACT

Asthma is a respiratory illness, characterised by a history of respiratory symptoms that vary in time and intensity, such as wheezing, shortness of breath, chest tightness, and coughing, as well as fluctuating expiratory airflow restriction. In Ayurveda, it is detailed explained under the heading of *Tamaka Shwasa*. A 58-year-old female patient of Bronchial Asthma came to our hospital. Considering case of *Tamaka Shwasa*, *Shodhana* in the form of *Vamana* was planned. *Snehapana* (Therapeutic internal oleation) was given with *Kantakarighrita* (Medicated Ghee) followed by *Vamana*. Other internal medication was given and follow up was taken for 6 months. Effect of treatment was assessed through objective parameters like AEC, FVC(L), FEV1 (L), FVC/FEV1(%) ratio and subjective parameters by asthma control questionnaire score. Effect of intervention found substantial improvements were seen in subjective and objective parameters. In addition, with significant improvement in symptoms of bronchial asthma, her dosage of previous medication was reduced. *Vamana* with oral ayurvedic medication is very effective in bronchial asthma along with improvement in quality of life. Integrated approach can be encouraged for management of Bronchial Asthma.

Keywords: Ayurveda, Spirometry, *Tamaka Shwasa*, *Kantakarighrita*, *Vamana*.





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INTRODUCTION

Asthma is a heterogenous disease, usually characterized by chronic airway inflammation. It is defined by the history of respiratory symptoms, such as wheeze, shortness of breath, chest tightness and cough, that vary over time and intensity, together with variable expiratory airflow limitation.[1] Prevalence is steadily increasing and is three times higher than mortality and more than twice as high as DALYs (disability-adjusted life years) in India compared to the global share of asthma burden.[2] Based on the INSEARCH (Indian Study on Epidemiology of Asthma, Respiratory Symptoms and Chronic Bronchitis in Adults), asthma prevalence of 2.04% represents a tremendous total burden of more than 17 million people.[3] The pathogenesis of asthma is mainly dependent on inflammation along with bronchoconstriction, hyper responsiveness and remodelling of airway.[4] Common risk factors of asthma include exposure to allergens, (such as house dust, mites, animal fur, cockroaches, pollens, and mold) occupational irritants and genetic predisposing factors.[5] and its management includes different modalities like SABA (Short-acting beta-agonists), ICS (Inhaled corticosteroids) - containing controller etc and long-term goals of asthma management is to achieve good symptom control, and minimize future asthma risk.[1] In Ayurveda, a disease characterized by respiratory distress comes under *Shwasa-roga*. (Respiratory disease). *Tamaka Shwasa* is one of the five types of *Shwasa*, and considering the signs and symptoms, it can be compared with bronchial asthma.[6] It is a *Kapha-vata* predominant disease, manifesting in *Urah-pradesh* (Thoracic cavity) showing involvement of *Pranavaha Srotasa* (Channels of respiration). *Nidana* (Risk factors) of *Shwasa-roga* are exposure to *Raja* (Dust), *Dhuma*, (Smoke) *vata* (breeze) etc.[7] Pathophysiology includes obstruction in the *Pranavaha Srotasa* (Channels of respiration) and upward movement of vitiated *Vata dosha*. [8] Hence, in Ayurveda the main objective of management of asthma is to balance the vitiated *Doshas* through *Shamana* (Palliative) and *Shodhana* (Bio-cleansing) therapies. *Vamana* (Therapeutic emesis) is one of the *Shodhana* (Bio-cleansing) therapies, which is mainly indicated for *Kapha* predominant condition.[9] and the primary cause for *Shwasa* is imbalance of *Kapha-vata Doshas*, so *Vamana* can be considered as a choice of treatment for asthmatic patients. In view of this, an attempt was made to study the clinical efficacy of *Vamana* with oral medications in the management of asthma by reducing acute attacks and improving the quality of life of asthma patients.

PATIENT AND METHODS

A 58-year-old female patient came to the reputed Ayurveda Hospital on date 03/04/2023 with the following complaints:

- Difficulty in breathing, more on exertion.
- Coughing with white sputum.
- Congestion and heaviness in the chest region.
- Mild pain in chest region while coughing.

Case Details

She was suffering from these complaints from last 8 years. The condition was diagnosed as Bronchial Asthma by a pulmonologist and treated for the same with adequate Asthma treatment including Budesonide at 320ug + Formoterol at 9ug b.i.d. combination, Montelukast 10mg/day, and oral bronchodilators (Deriphylline 150mg once in a day). But no satisfactory improvement was observed in her condition. Gradually, the above-mentioned symptoms increased in severity over the last 3 years. Patient was willing to take herbal medication to get relief from above said symptoms. She was a known case of Hypertension from 3 years and on regular medication (Atenolol 25mg once in a day). She had a history of allergy to dust, smoke, and pollen grains. No history of diabetes, thyroid disorder, or any trauma or surgery was present. The patient was vegetarian. She had a history of unsatisfactory passing of stool once or twice in a week. Frequency of urine 3-4 times/day & 0-2 times/night, normal sound sleep, and had no addictions.

Clinical Findings

Vitals of the patients were BP- 110/60 mm of Hg, pulse 68/min. A systemic examination of the patient revealed no abnormalities except the Respiratory system and she had a normal gait, absence of pallor, icterus, clubbing, or cyanosis, also no palpable lymph node was noted on examination. On Respiratory system examination,





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- Inspection: Normal shape of chest and B/L symmetrical
- Palpation: Trachea normal, centrally placed; Tactile Fremitus equally distributed.
- Percussion: Normal Resonant sound heard
- Auscultation: Air entry reduced on all lobes of the lungs + Mild Wheezing sound heard on upper lobes of B/L lungs.

Therapeutic Interventions

On the basis of above clinical findings and examination patient was diagnosed as *Tamaka shwasa* and predominantly deranged *dosha* were *Kapha-vata*. Assessment of patient was done for suitability of *Shodhana* therapy. Considering *Kapha doshadhikya* (excess of productive cough) *Vamana* was planned. After completion of *Shodhana*, *Shamana* was given in the form of internal medication. Oral bronchodilator and corticosteroid were gradually tapered. Details of the treatment algorithm like modalities, intervention, frequency, mode of administration etc are listed in table 1 to 3.

OBSERVATION AND RESULT

Patient's condition was assessed on different intervals on Objective and Subjective parameters as outlined in Table 4 and 5. After the course of *Vamana*, the patient had a significant decrease in coughing, heaviness of chest, and improved sleep. AEC was enormously decreased, and prior studies suggest that *Vamana Karma* lowers histamine levels in the body. [10] As a result of decreased airway blockage and removal of blocked mucus, FVC and FEV1 values increased within 15 days of treatment. After 60 days of treatment breathlessness, coughing and usage of ICS was reduced. During the course of treatment, no any adverse event was seen.

DISCUSSION

Bronchial asthma is an episodic condition characterized clinically by bouts of dyspnoea, coughing, and wheezing. However, a severe and extreme form of asthma known as Status asthmaticus and all the patient of asthma are at risk of status asthmaticus and if not diagnosed and treated appropriately, it can be deadly. [12] Recent guidelines of asthma advises that all asthmatics above the age of 5 years should be treated with regular or (for mild asthma) as-needed inhaled corticosteroids to control the symptoms and avoid flare-ups (also known as exacerbations or "attacks"). [13] Despite of available treatment and guidelines, around 60.1% of asthmatic patients are still suffering from uncontrolled asthma and the percentage of this was seen more in females (63.1%) than males (54.7%). [14] Ayurveda emphasis more on obstruction of the *Strotas* (Channels) and the key factors for manifestation of *Shwasa-roga* (Respiratory illness) are vitiation of the *Vata* and *Kapha* dosha along with obstruction in the *Pranavaha Strotas* (respiratory channels). The therapeutic treatment for *Tamaka Shwasa* involves the use of drugs and therapies aimed at *Vata-Kapha Hara* (balancing), *Ushna* (hot potency), and *Vatanulomana* (mild purgative action) characteristics. [15] For *Shodhana* (bio-cleansing) therapy, *Vamana* (Therapeutic emesis) and *Virechana* (Therapeutic purgation) are beneficial based on status of *Doshas*. In the present case, *Vamana* therapy was chosen as the mode of treatment because dominancy of *Kapha Dosh* along with *Pitta* and *Vata* was seen and only *Vamana* therapy is capable of eliminating *Kapha Dosh* in greater proportions in a shorter period of time, resulting in faster and long-lasting relief from symptoms. As a preparatory step for *Vamana*, *Kantakarighrit* was selected for internal oleation as it is indicated for *Kapha-vyadhi* and it also possess anti-inflammatory, antiasthmatic and antimicrobial properties, proven through various *in-vivo* and *in-vitro* studies. [16,17,18] *Dashmoola Katutrayavati* is having *Kaphavatahara* and *Kasashwasahara* properties and is useful in asthma, bronchitis due to its anti-inflammatory and analgesic properties. [19,20] *Bharnagyadikashaya* have *Aampachana* (detoxification of metabolic toxins) and *Kaphavatahara* properties and is widely used in the cough, asthma and fever. [21] *Vata-anulomana* and regulation of agni is important for the treatment of *shwasaroga*, so *Erandbhrishthaharitaki* having *Rechana* (Purgative) property was given. [22] *Yastimadhughnavati* is having *Kanthya* (Good for throat), *Shwaskasahara* and *Rasayana* (Rejuvenator) properties and anti-asthmatic, antitussive, anti-inflammatory, broncho-dilatory, and antioxidant effects. [23,24,25] and *Chyavanprash* ensures the proper



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functioning of tracheobronchial tree of the respiratory system as it helps to treat respiratory infections, allergic cough, asthma, bronchospasm, seasonal or non-seasonal respiratory disorders[26] through its protective effect in pulmonary diseases.[27] Therefore, *Vamana* with internal medication gave encouraging result in the clinical symptoms of bronchial asthma such as reduction in the use of ICS, breathlessness, cough and getting sound sleep comparatively. The "Asthma Control Questionnaires" scale (Table No. 5) was used here also indicated that the patient's asthma was out of control with a mean score of 2.7 before treatment. However, after treatment, the mean score dropped to 1.28, demonstrating that the medication had successfully controlled the patient's asthma and relieved her symptoms. Eosinophils are associated with inflammatory processes, which can trigger airway inflammation and result in persistent airflow obstruction. [28] However, after *Vamana* therapy, the airflow obstruction may have got cleared leading to reduced inflammation in bronchioles and decrease in AEC. Significant changes were also seen in the values of Forced Vital Capacity (FVC), Forced Expiratory Volume in one second (FEV1), and the FEV1/FVC ratio after the treatment. (Table No. 4) Patient's major concern was the regular use of ICS and dyspnoea on minimal physical exertion, affecting her quality of life. Through this study, it was observed that the effect of *Vamana* sustained even after 15 days of treatment as patient didn't feel the need of inhaler on the daily basis which eventually improved the quality of life. After 1 month of *Vamana*, she was using inhaler SOS and same is continued after 6 months follow up.

CONCLUSION

The combined effect of *Vamana* with oral medication was observed in the patient with an objective of disrupting the progression of *Kaphavata Samprapti* using ayurvedic principles of *Kaphavatahara*, *Srotoshodhana* (cleansing of channels) and *Vatanulomana* (~balancing Vata dosha). This eventually led to reduction in the intensity of symptoms, dependence on the inhalers and improvement in the quality of life. Integrated approach is much needed in non-communicable diseases such as Bronchial Asthma to give optimum relief to the diseased and to improve the standard of living of community as well.

REFERENCES

1. Global Initiative for Asthma. Global strategy for asthma management and Prevention, 2023. Updated July 2023. Available from: www.ginasthma.org
2. Singh S. Prevalence, time trends and treatment practices of asthma in India: The Global Asthma Network study. ERJ open research. 2022 May;8(2):00528-2021.
3. Jindal SK. Indian study on epidemiology of asthma, respiratory symptoms and chronic bronchitis in adults (INSEARCH). The international journal of tuberculosis and lung disease: the official journal of the International Union against Tuberculosis and Lung Disease. 2012;16(9):1270–7.
4. Education, National Asthma, Program P. Third expert panel on the diagnosis and management of asthma. Expert panel report 3: Guidelines for the diagnosis and management of asthma [Internet]. 2007 Aug [cited 2023 Jul 8]. Available from: www.ncbi.nlm.nih.gov/books/NBK7223/.
5. Doddamani SH. Clinical efficacy of ayurvedic formulations, kanakasava and trivritchurna, in the management of bronchial asthma: A prospective openlabelmulticenter study. J Res Ayurvedic Sci [Internet]. 2020;4(1):1–9. Available from: <https://doi.org/10.5005/jras-10064-0096>.
6. MUNISHWAR NJ. Role of karpuradiarka as a new dosage form in the management of tamakshwasawsr to bronchial asthma: A case study". Journal of Ayurveda and Holistic Medicine (JAHM [Internet]. 2021;7(4). Available from: <http://www.jahm.co.in/index.php/jahm/article/view/413>.
7. Verma M, Deshpande S, Upadhyay K. A clinical study on the management of tamakashwasa W.S.R. to bronchial asthma with shrungyadishaarkar. International Journal of AYUSH Case Reports [Internet]. 2021 Jan;4(4):278–87. Available from: <https://ijacare.in/index.php/ijacare/article/view/171>
8. Tripathi B. Charaka samhita- shwasachikitsa- hindi translation. 1st ed. Chapter 17. Shloka. ChaukhambaSurbhartiPrakashan;



**Nishant Patel et al.,**

9. Tripathi B. Astangahrdayam of vagbhata, sutra sthana; vamanvirechaniya. Chapter. 18.
10. Patil SG, Thakar AB. Efficacy of vamaana karma with ikshvakuksheera yoga in the management of tamakashvasa (bronchial asthma. Ayu. 2017;38(1-2):10–4.
11. Juniper EF. Development and validation of a questionnaire to measure asthma control. The European respiratory journal. 1999;14(4):902–7.
12. Chakraborty RK, Basnet S. Status asthmaticus [Internet]. National Library of Medicine. 2022 [cited 2023 Jul 8]. Available from: www.ncbi.nlm.nih.gov/books/NBK526070/.
13. Levy ML. Key recommendations for primary care from the 2022 global initiative for asthma (GINA) update. NPJ Primary Care Respiratory Medicine [Internet]. 2023;33(1):7,. Available from: <https://doi.org/10.1038/s41533-023-00330-1>.
14. Health E. Uncontrolled Asthma among Adults. Centers for Disease Control and Prevention [Internet]. Centers for Disease Control and Prevention. 2019. Available from: www.cdc.gov/asthma/asthma_stats/uncontrolled-asthma-adults-2019.htm.
15. Acharya YT, editor. Charaka Samhitha of Agnivesha. In: ChikitsaSthana. Reprint Edition. Ch. ChaukhambaSurbharatiPrakashana; p. 539.
16. More SK, Lande A, Jagdale P, Adkar P, Ambavade S. Evaluation of anti-inflammatory activity of Solanum xanthocarpum Schrad and Wendl (Kantakari) extract in laboratory animals. Ancient science of life. 2013;32(4):222–6.
17. Gupta RK. Hepatoprotective effect of Solanum xanthocarpum fruit extract against ccl4 induced acute liver toxicity in experimental animals. Asian Pacific journal of tropical medicine. 2011;4(12):964–8.
18. Sravanthi K. Evaluation of anti-inflammatory and analgesic potency of whole plant extract of solanum surattense in experimental animals. Research Journal of Pharmacology and Pharmacodynamics. 2013;5(2):101–5.
19. Parekar RR. Experimental evaluation of analgesic, anti-inflammatory and anti-platelet potential of dashamoola. Journal of Ayurveda and Integrative Medicine [Internet]. 2015;6(1):11–8,. Available from: <https://doi.org/10.4103/0975-9476.146565>.
20. Ayurvedic formulary of india." ayurvedic formulary of india part 1. The Controllers of Publication;
21. Chaudhari B. A clinical evaluation of kaphajakasa (chronic or recurrent mucopurulent bronchitis) -a case study. Elementary Education Online. 2021;20(5):5184.
22. Ghosh KA, Tripathi PC. Clinical Effect of Virechana and Shamana Chikitsa in Tamaka Shwasa (Bronchial Asthma. Ayu [Internet]. 2012;33(2):238–42,. Available from: <https://doi.org/10.4103/0974-8520.105244>.
23. Rabbani F. The efficacy of an oral formulation of glycyrrhiza glabra, viola odorata, and operculinaturpethum as an add-on therapy for mild-to-moderate childhood asthma: A randomized placebo-controlled clinical trial. Journal of Research in Pharmacy Practice [Internet]. 2023 Mar;11(3):116–23,. Available from: https://doi.org/10.4103/jrpp.jrpp_77_22.
24. Pal PK, Sarkar B, Singh H, Pal S, Kumar V, Babu G, et al. QUALITY CONTROL STANDARDIZATION and ANTI-INFLAMMATORY ACTIVITY of AYURVEDA FORMULATION YASHTIMADHU CHURNA. Plant Archives. 2021;21(2):21–2.
25. Hasan MK. Phytochemistry, pharmacological activity, and potential health benefits of glycyrrhiza glabra. Heliyon [Internet]. 2021 Jun;7(6). Available from: <https://doi.org/10.1016/j.heliyon.2021.e07240>.
26. Sharma R. Chyawanprash: A traditional indian bioactive health supplement. Biomolecules. 2019 Apr;9(5):161.
27. Kumar S. Evaluation of anti-inflammatory and immunomodulatory activity of Chyawanprash on particulate matter-induced pulmonary disease in mice. Journal of Ayurveda and integrative medicine. 2021;12(4):649–56.
28. Solomon Y. Peripheral blood eosinophilia in adult asthmatic patients and its association with the severity of asthma. BMC pulmonary medicine. 2023 Mar;23(1):96.





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Table 1 : Treatment Plan for Preparatory procedures

Sn.	Treatment Modalities	Intervention	Frequency	Anupana	Mode of administration
Treatment From 04/04/2023 to 12/04/2023 Purvakarma (Preparatory procedures) (Day 0)					
1	<i>Deepana Pachana</i> (To enhance metabolic fire and digestion)	<i>Chitrakadi Vati</i>	500 mg twice a day for 4 days	Lukewarm water	Orally Before food
2	<i>Deepana Pachana</i> (To Enhance metabolic fire and digestion)	<i>Sunthi Musta Sidhhajala</i>	As a drinking water for 4 days	---	Orally
3	<i>AbhyantaraSnehapana</i> (Internal oleation)	<i>KantakariGhrita</i> (Medicated ghee)	Day 1- 30 ml Day 2- 60 ml Day 3- 90 ml Day 4- 120 ml Day 5- 150 ml	Lukewarm water	Orally Empty stomach in early morning around 7:00 AM
Vishram kala (Therapeutic resting period) on13/04/2023					
7	<i>BahyaSnehana</i> (External Oleation)	<i>MurchitaTila Taila</i> (Medicated oil)	Once in morning	--	External
8	<i>Bahya Mrudu Swedana</i> (Mild sudation therapy)	<i>Bashpa Sweda</i> (Sudation therapy)	Once in Morning	--	External
9	<i>Kapha Dosha Utklesh Ahara</i> (Food that increase kapha dosha)	<i>Pedha, Gulab Jamun, Dahi Vada Mendu Vada</i> Rice	Whole Day	--	Oral

Table 2: Main Therapeutic Procedures

Pradhana Karma (Main therapeutic procedures) on 14/04/2023					
Sn.	Treatment Modalities	Intervention	Frequency	Anupana	Mode of administration
1	<i>BahyaSnehana</i> (External Oleation)	<i>MurchitaTila Taila</i> (Medicated oil)	Once in Early morning (5:30-6 :00AM)	--	External
2	<i>Bahya Mrudu Swedana</i> (Sudation therapy)	<i>Bashpa Sweda</i> (Sudation therapy)	Once in Early morning (5:30-6 :00AM)	--	External
3	<i>Akantha Pana</i> (Full Stomach drink)	Milk	2300 ml		
4	<i>Vamana Kalpa</i> (Medicinal formulation to induce Vamana)	<ul style="list-style-type: none"> <i>MadanaphalaChurna</i> -5 gm (Powder of seed of <i>Randia dumetorum</i>) <i>Vacha Churna</i>-1 gm (Powder of <i>Acorus calamus</i>) <i>Saindhav Lavana</i> (rock salt) - 2 gm Honey - Q.S 	~ 10 gm		
5	<i>Vamanopaga Dravya</i> (Supportive medication to	<i>Yashtimadhu Phanta</i> (Infusion of <i>glycyrrhiza glabra</i>)	1000 ml		





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	continue vomiting)			
6	Vamana vega (Projectile vomiting bouts)	7 Vega		
7	Vaman Paschyata Karma (Post therapy procedure)	Gandush-kavala(Gargling) with warm water		
		Dhoomapana(Medicated Smoking)		
8	Sansarjana Karma (Special dietetic schedule)	Sanjarna Karma chart (Special Diet Plan) given to patient for 5 Days From 15/04/2023 to 20/04/2023 considering Madhyam Shuddhi		

Table 3:Follow up Medications

Follow Up Medication on 20/04/2023 for 15 days (Day 15)					
Sn.	Treatment Modalities	Intervention	Frequency	Anupana	Mode of administration
1	Shamana Aaushdhi (Palliative medicine)	DashmoolaKatutryavati	500mg thrice a day	Lukewarm water	Oral Before food
		Bharangyadi Kashaya	40 ml twice a day	Lukewarm water	Oral Before food
		KantakariGhrita	5gm/ml twice a day	With food	Oral Empty stomach
Follow up Medication on 02/05/2023 for 30 days (Day 30)					
1	Shamana Aaushdhi (Palliative medicine)	Erandbhrishtaharitaki	500mg at night	Lukewarm water	Oral Before food
		Yastimadhughanavati	250mg for chewing	Lukewarm water	Oral
		Bharangyadi Kashaya	40 ml twice a day	Lukewarm water	Oral Empty stomach
		Chyawanprash	1 tsp twice a day	-	Oral Empty stomach
Follow up medication on 05/06/2023 (Day 60)					
1	Shamana Aaushdhi (Palliative medicine)	Chyawanprash	2 tsp once a day	-	Oral Empty stomach
		Bharangyadi Kashaya	40 ml twice a day	Lukewarm water	Oral Empty stomach

Table 4: Objective Parameters

Parameters	Day 0	Day 30	Day 60	
PFT	FVC(L)	1.50	1.64	ND
	FEV1 (%)	66	83	
	FEV1/FVC (%)	65.60	70.18	
AEC	Cells/uL	622	460	450

Note: FVC – Forced vital capacity, FEV1- Forced Expiratory volume in one second, FEV1/FVC: Ratio of the forced expiratory volume in the first one second to the forced vital capacity of the lungs, ND – Not Done.





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Table 5: Subjective Parameters

Asthma Control Questionnaires [11]						
No	Question	Gradation	Day 0	Day 15	Day 30	Day 60
1	On average, during the past week, how often were you woken by your asthma during the night?	0 = never 1 = hardly ever 2 = a few times 3 = several times 4 = many times 5 = a great many times 6 = unable to sleep because of asthma	3	2	2	2
2	On average, during the past week, how bad were your asthma symptoms when you woke up in the morning?	0 = no symptoms 1 = very mild symptoms 2 = mild symptoms 3 = moderate symptoms 4 = quite severe symptoms 5 = severe symptoms 6 = very severe symptoms	2	2	1	1
3	In general, during the past week, how limited were you in your activities because of your asthma?	0 = not limited at all 1 = very slightly limited 2 = slightly limited 3 = moderately limited 4 = very limited 5 = extremely limited 6 = totally limited	2	2	1	1
4	In general, during the past week, how much shortness of breath did you experience because of your asthma?	0 = none 1 = very little 2 = a little 3 = a moderate amount 4 = quite a lot 5 = a great deal 6 = a very great deal	4	2	2	1
5	In general, during the past week, how much of the time did you wheeze?	0 = not at all 1 = hardly any of the time 2 = a little of the time 3 = a moderate amount of the time 4 = a lot of the time 5 = most of the time	3	1	1	1





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		6 = all of the time				
6	On average, during the past week, how many puffs of short-acting bronchodilator have you used each day?	0 = None 1= 1-2 puffs most days 2 = 3-4 puffs most days 3 = 5-8 puffs most days 4 = 9-12 puffs most days 5 =13-16 puffs most days 6 = More than 16 puffs most days	1	1	0	0
7	FEV1 % Predicted	0 > 95% predicted 1 95-90% 2 89-80% 3 79-70% 4 69-60% 5 59-50% 6 < 50% predicted	4	--	2	--
Mean	2.7	---	1.28	--		





A Scientometric Analysis of Phenacetin Retrieved from Web of Science Database

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ABSTRACT

Phenacetin a component derived from Aspirin-phenacetin-caffeine is a Pharmaceutical drug used for painkiller. This is a quite common drug used since the 18th Century. In this research work, A total of 1309 bibliographic records related to Phenacetin was collected from the Web of Science (WoS) database and were analyzed to submit a report the Scientific state in related to Authors, Journals, Countries and Categories. Histcite and VoSviewer software's are the tools used for analyzing the records. The study also analyze the annual contribution, authorship pattern, language, lotka's law, authors, institutions, sources, countries and co-occurrence keywords. The results indicate that USA and China are the most contributing countries in Phenacetin. This study therefore, provides an extensive understanding about the trends and research patterns of Phenacetin efforts worldwide. Finally the research gaps are highlighted and the scope for future also discussed.

Keywords: *Phenacetin. Histcite. VoS Viewer, Lotka's Law*





INTRODUCTION

Phenacetin, painkiller was the world's first synthetic pharmaceutical drug. Harmon Northrop Morse American chemist, in 1878 developed Phenacetin and introduced into the pharmaceutical market in 1887. It was one of the first painkillers that was not derived from opium while at the same time being absent of anti-inflammatory qualities. Phenacetin is a component of APC (aspirin-phenacetin-caffeine) and it has been used as an analgesic and fever-reducing drug in both human and veterinary medicine for many years. Phenacetin alone was available in 250 and 300 mg doses as tablets, and up to 500 mg doses as powder. Analgesic mixtures containing phenacetin were previously marketed as tablets or capsules containing between 150 and 300 mg phenacetin. As a combination 150 mg phenacetin + 230 mg aspirin, + 15 or 30 mg caffeine; or 150 mg phenacetin + 230 mg aspirin + 30 mg caffeine + 8, 15, 30, or 60 mg codeine phosphate. The usual dose was 300 mg 4–6 times per day, and the daily dose was not to exceed 2 g.[1,2] Phenacetin was also used in the preparation of hair-bleaching agents as a hydrogen peroxide stabilizer. It was withdrawn from the market of Canada in 1978, in the United Kingdom in 1980 and in the United States of America in 1983. Over-the-counter sales of phenacetin-containing analgesics have been legally prohibited in most countries. However, it was withdrawn in 1983 in the United States due to unacceptable levels of interstitial nephritis in patients and potential risks of tumorigenicity[3]. The use of phenacetin causes major metabolites in humans. After the ban of Phenacetin, Acetaminophen has served as the major substitute in many analgesic brands. There is no evidence to-date that usage of acetaminophen is associated as carcinogenic chemical. During the treatment of Colon cancer, an inhibitory action of cyclooxygenase enzyme acted as mediator where the usage of Anti-inflammatory, Non-Steroidal inclusion in the treatment gives chemopreventive measures[4]. While there has been a dramatic increase in acetaminophen consumption in recent years, there has been a sharp decrease in worldwide use of phenacetin. This is primarily attributable to kidney toxicities and possible tumors associated with the abuse of phenacetin [5].

In Australia, analgesic mixtures containing phenacetin were legally banned in 1977, in Belgium in 1987, in Germany in 1986, and in Denmark in 1985. In the Czech Republic, analgesic mixtures containing phenacetin were recently removed from the market[6-8]. They are still available in Hungary under the trade names Antineuralgica and Dolor. Phenacetin was withdrawn from many analgesic mixtures long before the legal ban in several countries. There is *sufficient evidence* in humans for the carcinogenicity of phenacetin. Phenacetin causes cancer of the renal pelvis, and of the ureter. For the overall evaluation of phenacetin, the Working Group took into consideration that tumours of the renal pelvis and ureter are not known to result from the other components of the analgesic mixtures used in most countries; namely, aspirin, codeine phosphate, and caffeine. [9,10] Phenacetin is an odorless fine white crystalline solid with a lightly bitter taste, slightly soluble in water and benzene, acetone, pyrimidine and used as an analgesic medicine [11,12]. Phenacetin is a class of acetamides in which one of the hydrogens attached to the nitrogen and is substituted by 4-ethoxyphenyl group. It is functionally related to N-phenylacetamide, 4-ethoxyaniline and a paracetamol. Human ingestion of phenacetin can result in a bluish discoloration of the skin due to a lack of oxygen in the blood (cyanosis), dizziness and respiratory depression. It is reasonably anticipated to be a human carcinogen[13]. Exposure of phenacetin symptoms may include weakness, dizziness, depression, collapse, cyanosis, sweating, gastric irritation, chills, fall in blood pressure, jaundice, coma, convulsions, weight loss, insomnia, shortness of breath, aplastic anemia, and damage to the liver, kidneys, heart and central nervous system [14]. It is also used in the preparations of hair bleaching as a hydrogen peroxide stabilizer. Phenacetin is a potential candidate for rotary kiln and fluidized bed forms of incineration. It should be stored in a securely sealed, watertight container also should be enclosed in a second, unbreakable, leakproof container. Smoking, drinking, and eating should be prohibited in phenacetin work areas, and cleanliness following the handling of phenacetin should be emphasized [15,16].

METHODOLOGY

During the searching of documents, the keyword search topic "ALL - Phenacetin" is used. Initially, when we searched by topic, total of 1309 documents are found out. Thereafter, the keyword search function is used. After



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choosing the database, the mapping knowledge of clean energy is introduced by using HistCite and VoS viewer. It is carried out to identify the distribution of the number of documents by various parameters such as the year of publications, the journals, The contribution made by Authors of different institutes, different countries, using different keywords, and through their productivity. The tool is capable of generating a distance-based visual representation of networks, where each distance between two nodes denotes the degree of their closeness. Using this approach, the influences of countries, journals, authors, and keywords in our research domain can be identified.

Annual growth of publication

During the study, a period from 1989-2023 has been taken into account. Table 1 and Figure 1 show the rise of research papers in the field of Phenacetin literature and a total of 1309 publications were found to be published. The biggest number of articles 64 or 4.9% were published in 2015, while the lowest numbers of research articles 10, or 0.8% were published in 1989. In the year 2014 with 63.4 or 8% has been recorded for the second largest number of articles. The research output of phenacetin has been steadily decreasing as well as increasing.

Language contribution on Phenacetin

Table 2 and Figure 2 showed that Phenacetin published in nine languages between 1989 and 2023. A total of 1309 documents were published and it is also found that through English language most of the contribution were published 1267 (96.8 %). Czech and Russian were the language with the smallest contribution. 1 (0.1 %).

Authors Collaboration in Phenacetin

The most common kind of collaboration network is the co-authorship network. The network visualization of authorship in the field of phenacetin research is depicted in Fig.3. The circles (or nodes) represents the author and the size of the circles represents the number of papers published. There can be seen some links between two circles standing for cooperative relation between two authors and the thickness between the links represents the strength of cooperation. The leading 30 authors with 15 more papers in collaboration are Wen, Congcong, Fukami, Tatsuki, Wang, Xianqin, Guengerich, FP, Hu, Lufeng, Nakajima, Miki and Greenblatt, DJ.

Contributing Countries analysis

Different countries contributed to this domain and it also has been examined. Table 4 summarizes the findings of our investigation. The contributions of several countries were indicated in Figure.4. With 298 publications, the People's Republic of China is at the top of the list. With 246 publications, the USA is rated second on the list, followed by Japan in third place in the list with 151 publications. Following them, Germany (79), England (61), India (52), France (47), and South Korea (44) have shown their respective research outputs in terms of the number of publications. Using VOS viewer, each node represents a country and every publication creates a link between the co-authors. Node size represents the country's comprehensive impact. Thus, bigger the node is the higher collaborative capability and impacts the country.

Institution

Institution analysis facilitates the researchers to identify the dominating institutions working actively in the specified research domain for their postdoctoral studies, research exchange activities and study tours. Institution have participated in the studies related to Phenacetin during the period of 1989 to 2023. Top institutions are shown in Fig. 5 and Table 5. Wenzhou med university has contributed highest publication occupy first place. Kanazawa university has attained second place and Vanderbilt university has occupied third place.

Journals

Table 6 and Fig.6 presented the ranking of journal with number of literature published on the source. The journals were only highlighted since it can be seen from the Fig.6 that, Drug metabolism and disposition the highest with 95 (6710 citations) published, followed by Xenobiotica with 44 (1126 citations) and Biochemical pharmacology with 27 (2129 citations).



**Rajeswari and Kanimozhi****Keyword analysis**

The contributions of different Co-occurrence keywords in this domain have been analyzed. The results from our investigations are depicted in Table 7 and the contributions of different Co-occurrence keywords were depicted in Figure.7. Phenacetin is ranked top in the list with 341 publications. The metabolism makes its position second in the list with 173 publications and pharmacokinetics ranked in third place in the list with 137 publications. Using VOS viewer, it can be observed that the network of co-occurrence of keywords clearly showed the main aspects addressed in the area and also provides an approximate view for future research.

Author Productivity

The author productivity in the phenacetin was estimated using Lotka's law [17] and the results are provided in Table 8; where x denotes the number of articles published by an author, c is the productivity constant, and $f(x)$ is the fraction of authors with x published articles. Based on Lotka's law calculations for phenacetin, 0.793, and 0.118 of the proportion of authors contributed single articles and double articles respectively. Less than 0.1 of the proportion of authors provided the remaining number of articles. Based on author productivity, publication history, and impact factor were found that the growing of contributions.

Cited Articles

Chandrasekaran et al., synthesized the prostaglandin a nonsteroidal anti-inflammatory drugs by Two cyclooxygenase isozymes catalyze the rate-limiting step. The signal peptide is not cleaved from either protein and both proteins are glycosylated. COX-3, but not PCOX-1a, possesses glycosylation-dependent cyclooxygenase activity. Comparison of canine COX-3 activity with murine COX-1 and -2 demonstrates that this enzyme is selectively inhibited by analgesic/antipyretic drugs such as acetaminophen, phenacetin, antipyrine, and dipyron, and is potently inhibited by some nonsteroidal antiinflammatory drugs. Thus, inhibition of COX-3 could represent a primary central mechanism by which these drugs decrease pain and possibly fever[18,19]. Bonfiglio et al., developed a post-column infusion system to analyze endogenous plasma components which cause changes in the ESI response of model drug substances by the suppression of electrospray ionization (ESI) tandem mass spectrometry response. By enabling direct detection of these interfering components, this experimental system was used to analyze the ability of several common extraction procedures to remove Methyl-t-butyl ether (MTBE) liquid-liquid, Oasis and Empore solid-phase, and acetonitrile (ACN) protein precipitation sample preparation methods were tested using the post-column infusion system. In all cases, ACN protein precipitation samples showed the greatest amount of ESI response suppression while liquid-liquid extracts demonstrated the least. In addition, the three test compounds, phenacetin, caffeine, and a representative Merck compound, demonstrated that ESI response suppression is compound dependent.

Suppression was greatest with caffeine, the most polar analyte, and the smallest for the Merck compound, the least polar analyte [20]. Butler et al., reported the human hepatic microsomal caffeine 3-demethylation in humans, is selectively catalyzed by cytochrome P-450PA. Caffeine 3-demethylation was highly correlated with 4-aminobiphenyl N-oxidation ($r = 0.99$; $P < 0.0005$) in hepatic microsomal preparations obtained from 22 human organ donors, and both activities were similarly decreased by the selective inhibitor, 7,8-benzoflavone. The rates of microsomal caffeine 3-demethylation, 4-aminobiphenyl Noxidation, and phenacetin O-deethylation were also significantly correlated with each other and with the levels of immunoreactive human cytochrome P 450PA. The rabbit polyclonal antibody raised to human cytochrome P450PA was shown to inhibit strongly all three of these activities and to inhibit the N-oxidation of the carcinogen 2-naphthylamine and the heterocyclic amines, 2-amino-6-methyldipyrido- [1,2-a:3',2'-d]imidazole and 2-amino-3-methylimidazo[4,5-f - quinoline. Human liver cytochrome P-450PA was also shown to catalyze caffeine 3-demethylation, 4-aminobiphenyl N-oxidation, and phenacetin O-deethylation [21]. Walsky et al., represents the In vitro drug interaction data can be used in guiding the design of clinical drug interaction studies, or, when no effect is observed in vitro, the data can be used in place of an in vivo study to claim that no interaction will occur in vivo. To make such a claim, it must be assured that the in vitro experiments are performed with absolute confidence in the methods used and data obtained. To meet this need, 12 semiautomated assays for human P450 marker substrate activities have been developed and validated using approaches described in the GLP (good laboratory practices) as per the code of U.S. Federal Regulations. The assays that were validated are: phenacetin O-



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deethylase (CYP1A2), coumarin 7-hydroxylase (CYP2A6), bupropion hydroxylase (CYP2B6), amodiaquine N-deethylase (CYP2C8), diclofenac 4-hydroxylase and tolbutamidemethylhydroxylase (CYP2C9), (S)-mephenytoin 4-hydroxylase (CYP2C19), dextromethorphan O-demethylase (CYP2D6), chlorzoxazone 6-hydroxylase (CYP2E1), felodipine dehydrogenase, testosterone 6-hydroxylase, and midazolam 1-hydroxylase (CYP3A4 and CYP3A5). High-pressure liquid chromatography-tandem mass spectrometry, using stable isotope-labeled internal standards, has been applied as the analytical method. This analytical approach, through its high sensitivity and selectivity, has permitted the use of very low incubation concentrations of microsomal protein (0.01–0.2 mg/ml)[22]. Brosen K et al., demonstrated the fluvoxamine is a very potent inhibitor of the high-affinity O-deethylation of o-Phenacetin, which is catalysed by cytochrome. The apparent inhibitor constant of fluvoxamine, K_i , ranged from 0.12 to 0.24, μM and seven other SSRIs, citalopram, N-desmethylcitalopram, fluoxetine, norfluoxetine, paroxetine, sertraline and litoxetine either did not inhibit or were weak inhibitors of the O-deethylation of phenacetin. Their findings also give the mechanism of the pharmacokinetic interactions between fluvoxamine and drugs that are metabolized by CYP1A2, e.g. theophylline and imipramine[23]. Kalow, W; Tang, Bk studied the solubilities in binary solvent mixtures by means of the inverse Kirkwood-Buff integral (IKBI) and the quasi-lattice quasi-chemical (QLQC) methods for the preferential solvation parameters, i.e., the differences between the local and bulk mole fractions of the solvents in solutions of certain drugs and polycyclic aromatic hydrocarbons (PAHs). The solutes include caffeine, niflumic acid, diazepam, benzocaine, phenacetin, paracetamol, nalidixic acid, anthracene, and *trans*-stilbene and both aqueous and non-aqueous mixtures are considered. The findings are rationalized in terms of the interactions between the solute and solvents and the solvent components among themselves [24]. Yuan, R et al., determine the effect of the drug on *in vitro* probe reactions for specific P450 enzymes to evaluate the potential for a new drug to modify the cytochrome.

The *in vitro* findings obtained with one probe substrate are usually extrapolated to the compound's potential to affect all substrates of the same enzyme. Due to this practice, it is important to use the right probe substrate and to conduct the experiment under optimal conditions. Surveys conducted by reviewers in CDER indicated that the most common *in vitro* probe reactions used by industry investigators include the following: phenacetin O-deethylation for CYP1A2, coumarin 7-hydroxylation for CYP2A6, 7-ethoxy-4-trifluoromethyl coumarin O-dealkylation for CYP2B6, tolbutamide 4-hydroxylation for CYP2C9, S-mephenytoin 4-hydroxylation for CYP2C19, bufuralol 1-hydroxylation for CYP2D6, chlorzoxazone 6-hydroxylation for CYP2E1, and testosterone 6-hydroxylation for CYP3A4. For CYP3A4-based drug interactions it may be necessary to evaluate two or more probe substrates. In many cases, the probe reaction represents a particular enzyme activity only under specific experimental conditions. Investigators must consider appropriateness of probe substrates and experimental conditions when conducting *in vitro* drug interaction studies and when extrapolating the results to *in vivo* situations[25]. Boobis, et al., reported urothelial atypia in three patients with CHN, with the subsequent development in one patient of overt transitional cell carcinoma (TCC). Multifocal high-grade flat TCC *in situ* (carcinoma *in situ*; CiS) was observed, mainly in the upper urinary tract, in four patients, a prevalence of 40%. In one of those patients, a superficially invasive flat TCC of the right upper ureter, as well as two additional foci of noninvasive papillary TCC, were found in the right pelvis and left lower ureter, respectively. The patient also recurrent noninvasive papillary TCC of the bladder. Furthermore, in all cases, multifocal, overall moderate atypia was found in the medullary collecting ducts, pelvis, and ureter. All CiS and papillary TCC, as well as urothelial atypia, overexpressed p53. These results show that the intake of Chinese herbs containing AA has a dramatic carcinogenic effect. Carcinogenesis is associated with the overexpression of p53, which suggests a role for a p53 gene mutation. The relationship of this mutation with the reported presence of AA DNA adducts in the kidney remains to be explored [26].

CONCLUSIONS

The purpose of this study is to conduct a scientometric analysis of phenacetin research in order to understand the growth of literature in the discipline, the pattern of publications and the impact of research. Using publications data from Web of Science database, this study provides a quantitative and qualitative description of phenacetin research covering a period of 25 years. Through this study, USA is highest in the world ranking in phenacetin research. Hence,



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it is important that stakeholders pay special attention to academic and research organizations in the country encouraging them to undertake more and more new research projects, programmes in collaboration with international hubs in phenacetin research.

REFERENCES

1. Bringuier PP, McCredie M & Sauter G. (1998). Carcinomas of the renal pelvis associated with smoking and phenacetin abuse: p53 mutations and polymorphism of carcinogen-metabolising enzymes, *International Journal of Cancer*, 79, 531–536.
2. Fischbach T, Lenk W Sackerer D (1977). Additional routes in the metabolism of phenacetin. In: Biological reactive intermediates. Jollow DJ, Kocsis JJ, Snyder R, Vainio H, editors. New York: Plenum Press, pp. 380–386.
3. Gad, S.C. (2014). Encyclopedia of Toxicology (Third Edition).
4. Bladder Cancer: Epidemiology, Mimi C. Yu, Ronald K. Ross, in Encyclopedia of Cancer (Second Edition), 2020
5. Jack A. Hinson. (1983) Reactive Metabolites of Phenacetin and Acetaminophen: A Review, *Environmental Health Perspectives*, 49, 71–79.
6. Hinson JA & Mitchell JR. (1976) N-Hydroxylation of phenacetin by hamster liver microsomes. *Drug Metabolism and Disposition*, 4, 430–435.
7. Isaka H, Yoshii H & Otsuji A, (1979). Tumors of Sprague-Dawley rats induced by long-term feeding of phenacetin, *Gann*, 70, 29–36.
8. Johansson SL, Radio SJ, Saidi J & Sakata T. (1989) The effects of acetaminophen, antipyrine and phenacetin on rat urothelial cell proliferation. *Carcinogenesis*, 10, 105–111.
9. McCredie M & Stewart JH. (1988). Does paracetamol cause urothelial cancer or renal papillary necrosis?, *Nephron*, 49, 296–300.
10. Nakanishi K, Kurata Y & Oshima M. (1982). Carcinogenicity of phenacetin: long-term feeding study in B6c3f1 mice, *International Journal of Cancer*, 29, 439–444.
11. Australian National Drug Information Service: Profile on paracetamol. *Australian Journal of Pharmacy* 776: 857–863 (1984).
12. Cooper, S.A. (1981). Comparative analgesic efficacies of aspirin and acetaminophen, *Archives of Internal Medicine*, 141, 282–285.
13. Gazzard, B.G., Ford-Hutchinson, A.W, Smith, M.J.H. & Williams, R. (1973). The binding of paracetamol to plasma proteins of man and pig, *Journal of Pharmacy and Pharmacology*, 25, 964–967.
14. Lasagna, L., Davis, M. & Pearson, J.W. (1967) A comparison of acetophenetidin and acetaminophen I. Analgesic effects in postpartum patients. *Journal of Pharmacology and Experimental Therapeutics*, 155, 296–300.
15. Mitchell, J.R., Thorgiersson, S.S., Potter, W.Z., Jollow, D.J. & Keiser, H. (1974) Acetaminophen-induced hepatic injury. Protective role of glutathione in man and rationale for therapy. *Clinical Pharmacology and Therapeutics*, 16, 676–684.
16. Mukherjee, S. & Sood, S. (1980) A controlled evaluation of orally administered aspirin, dipyrrone and placebo in patients with postoperative pain. *Current Medical Research and Opinion*, 6, 619–623.
17. Barik, N., Jena, P.: (2021) Author productivity pattern and applicability of Lotka's inverse square law: a bibliometric appraisal of selected LIS open access journals, *Digital Library Perspectives*, 37(3), 223–241.
18. Chandrasekharan, NV, Dai, H; Roos, KLT, Evanson, NK, Tomsik, J; Elton, TS & Simmons, DL. (2002). COX-3, a cyclooxygenase-1 variant inhibited by acetaminophen and other analgesic/antipyretic drugs: Cloning, structure, and expression, *Proceedings of the national academy of sciences of the united states of America*, 99(21), 13926–13931. <http://dx.doi.org/10.1073/pnas.162468699>.
19. Guengerich, Fp & Shimada, T. (1991). Oxidation of toxic and carcinogenic chemicals by human cytochrome-p-450 enzymes, *Chemical research in toxicology*, 4(4), 391–407. <http://dx.doi.org/10.1021/tx00022a001>
20. Bonfiglio, R, King, RC, Olah, TV & Merkle, K. (1999). The effects of sample preparation methods on the variability of the electrospray ionization response for model drug compounds, *Rapid communications in mass*





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- spectrometry, 13(12), 1175-1185. [http://dx.doi.org/10.1002/\(SICI\)1097-0231\(19990630\)13:12<1175::AID-CM639>3.3.CO;2-S](http://dx.doi.org/10.1002/(SICI)1097-0231(19990630)13:12<1175::AID-CM639>3.3.CO;2-S)
21. Butler, Ma, Iwasaki, M, Guengerich, FP & Kadlubar, FF. (1989). Human cytochrome p-450pa (p-450ia2), the phenacetin o-deethylase, is primarily responsible for the hepatic 3-demethylation of caffeine and n-oxidation of carcinogenic arylamines - (aromatic-amines heterocyclic amines carcinogen metabolism), *Proceedings of the national academy of sciences of the United States of America*, 86(20), 7696-7700. <http://dx.doi.org/10.1073/pnas.86.20.7696>
 22. Walsky, RL & Obach, RS. (2004). Validated assays for human cytochrome P450 activities, *Drug metabolism and disposition*, 32(6), 647-660. <http://dx.doi.org/10.1124/dmd.32.6.647>
 23. Brosen, K, Skjelbo, E, Rasmussen, BB, Poulsen, HE & Loft, S. (1993). Fluvoxamine is a potent inhibitor of cytochrome-p4501a2, *Biochemical pharmacology*, 45(6), 1211-1214. [http://dx.doi.org/10.1016/0006-2952\(93\)90272-X](http://dx.doi.org/10.1016/0006-2952(93)90272-X)
 24. Kalow, W and Tang, BK. (1993). The use of caffeine for enzyme assays - a critical-appraisal, *Clinical pharmacology & therapeutics*, 53(5), 503-514. <http://dx.doi.org/10.1038/clpt.1993.63>
 25. Yuan, R, Madani, S, Wei, XX, Reynolds, K & Huang, SM. (2002). Evaluation of cytochrome P450 probe substrates commonly used by the pharmaceutical industry to study in vitro drug interactions, *Drug metabolism and disposition*, 30(12), 1311-1319. <http://dx.doi.org/10.1124/dmd.30.12.1311>
 26. Boobis, AR, Lynch, AM, Murray, S, Delatorre, R, Solans, A, Farre, M, Segura, J, Gooderham, NJ & Davies, DS. (1994). Cyp1a2-catalyzed conversion of dietary heterocyclic amines to their proximate carcinogens is their major route of metabolism in humans, *Cancer research*, 54(1), 89-94.

Table 1: Annual Growth of Phenacetin

Year	Publication	Percent	Citation
1989	10	0.8	858
1990	15	1.1	265
1991	44	3.4	2211
1992	33	2.5	1376
1993	49	3.7	2500
1994	35	2.7	1677
1995	30	2.3	1458
1996	43	3.3	1943
1997	46	3.5	2759
1998	47	3.6	2597
1999	48	3.7	2706
2000	34	2.6	1735
2001	41	3.1	1969
2002	35	2.7	3273
2003	22	1.7	1066
2004	34	2.6	1678
2005	18	1.4	574
2006	30	2.3	870
2007	35	2.7	1133
2008	24	1.8	828
2009	32	2.4	957





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2010	35	2.7	1387
2011	32	2.4	874
2012	52	4	1165
2013	55	4.2	881
2014	63	4.8	1213
2015	64	4.9	1391
2016	53	4	844
2017	36	2.8	894
2018	28	2.1	378
2019	42	3.2	382
2020	35	2.7	546
2021	40	3.1	352
2022	39	3	181
2023	30	2.2	47
	1309	100	44968

Table 2: Language contribution of phenacetin

Rank	Language	Publication	Percent	Citation
1	English	1267	96.8	44802
2	German	18	1.4	77
3	Chinese	10	0.6	34
4	French	4	0.3	25
5	Japanese	4	0.3	17
6	Portuguese	2	0.2	9
7	Spanish	2	0.2	2
8	Czech	1	0.1	2
9	Russian	1	0.1	0
		1309	100	44968

Table 3: Top 30 Authors Collaboration in Phenacetin

Rank	Authors	Cluster	Documents	Citations	Norm. citations
1	Wen, Congcong	2	20	161	8.3316
2	Fukami, Tatsuki	7	19	680	31.7143
3	Wang, Xianqin	2	18	265	12.6468
4	Guengerich, Fp	1	17	2743	48.0777
5	Hu, Lufeng	2	17	139	7.4353
6	Nakajima, Miki	7	17	513	24.2534
7	Greenblatt, Dj	5	15	1380	27.8373





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8	Boobis, Ar	4	13	928	20.7375
9	Chiba, K	1	13	1023	17.7525
10	Von Moltke, Ll	5	12	1223	24.3627
11	Yokoi, Tsuyoshi	7	12	559	24.1049
12	Davies, Ds	4	11	837	18.8972
13	Edwards, Rj	4	11	581	13.5503
14	Wang, Shuanghu	2	11	256	13.4693
15	Ma, Jianshe	2	10	222	10.88
16	Murray, S	4	10	738	15.1939
17	Shimada, N	1	10	987	16.3952
18	Harmatz, Js	5	9	972	19.2639
19	Lee, Sangkyu	1	9	71	3.9982
20	Lin, Guanyang	2	9	187	9.3392
21	Mccredie, M	3	9	231	4.4482
22	Nakajima, M	1	9	577	11.0084
23	Wang, Zhe	2	9	88	5.8134
24	Cai, Jinzhang	2	8	46	2.3343
25	Elseviers, Mm	3	8	254	4.9451
26	Fukushima, S	6	8	78	1.5445
27	Li, Wei	3	8	109	15.831
28	Yamazaki, H	1	8	649	11.8408
29	Yang, Suping	2	8	28	1.3554
30	Yokoi, T	1	8	518	9.9406

Table 4: Countries Collaboration in Phenacetin

Rank	Countries	cluster	Documents	Citations	Norm. citations
1	Peoples R China	3	298	4675	265.138
2	USA	5	246	15036	333.866
3	Japan	7	151	5911	140.22
4	Germany	2	79	2693	78.8273
5	England	7	61	3374	85.2208
6	India	3	52	565	27.3871
7	France	4	47	2442	66.4528
8	South Korea	3	44	903	36.6839
9	Brazil	4	39	832	49.1112
10	Spain	1	38	2105	66.1612
11	Sweden	5	30	1622	43.1276





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12	Canada	2	29	1675	33.429
13	Australia	6	28	1098	27.687
14	Italy	6	26	528	15.1686
15	Belgium	2	22	775	20.1402
16	Netherlands	4	18	406	12.1078
17	Switzerland	2	17	660	20.3576
18	Russia	1	16	294	12.1838
19	Finland	3	13	602	15.0519
20	Denmark	8	12	836	16.4123
21	Austria	2	11	159	5.4945
22	Poland	1	11	108	5.4933
23	Thailand	1	10	400	8.9153
24	Colombia	1	8	64	3.3983
25	Saudi Arabia	7	8	121	5.6986
26	Czech Republic	3	7	98	3.1718
27	Norway	1	7	189	7.8011
28	Hungary	2	6	64	2.8531
29	Mexico	9	6	61	1.8731
30	Scotland	5	6	116	4.2218

Table 5: Institution Collaboration in Phenacetin

Rank	Institution	cluster	Documents	Citations	Norm. citations
1	Wenzhou med univ	4	67	668	37.7388
2	Kanazawa univ	1	27	1022	37.5934
3	Vanderbilt univ	2	22	2862	52.3708
4	Chiba univ	5	16	650	11.6185
5	Nci	2	16	976	21.9384
6	China pharmaceutuniv	1	14	138	9.0769
7	Harvard univ	2	14	867	19.0079
8	Kyungpooknatluniv	3	14	108	6.5397
9	Tufts univ	3	13	1223	24.3627
10	Zhengzhou univ	3	12	76	5.6786
11	Shenyang pharmaceutuniv	3	11	249	12.2897
12	Univhelsinki	3	11	483	11.2816
13	Univsydney	2	11	305	8.4432
14	Univtoronto	1	11	685	11.475
15	Wenzhou med coll	4	11	78	3.5336





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16	Daiichi pure chem co ltd	1	10	987	16.3952
17	Nanjing agruniv	6	10	215	35.9052
18	Second mil med univ	7	10	80	2.8396
19	Univextremadura	6	10	772	22.4094
20	Cent s univ	5	9	160	4.9595
21	Chinese acad med sci	4	9	106	5.2196
22	Karolinskainst	2	9	599	18.1619
23	Natl insthlthsci	1	9	177	5.0322
24	Osaka city univ	1	9	129	3.3978
25	Chinese acadsci	3	8	144	5.5515
26	Shanghai jiao tong univ	7	8	70	4.1154
27	Tokyo univ pharm & life sci	5	8	184	3.6162
28	Univtexas	2	8	257	5.4358
29	Wenzhou peoples hosp	4	8	67	3.5014
30	Catholic univkorea	3	7	83	5.3509

Table 6: Journal Collaboration in Phenacetin

Rank	Journal	cluster	Documents	Citations	Norm. citations
1	Drug metabolism and disposition	1	95	6710	156.868
2	Xenobiotica	5	44	1126	31.2817
3	Biochemical pharmacology	3	27	2129	44.5313
4	Latin american journal of pharmacy	4	26	57	3.1766
5	Journal of pharmaceutical and biomedical analysis	2	24	574	19.6139
6	Journal of chromatography b-analytical technologies in the biomedical	2	22	508	17.961
7	Biomedical chromatography	4	21	293	13.9447
8	International journal of clinical and experimental medicine	4	18	95	4.7738
9	Forensic science international	2	17	630	36.4616
10	Journal of pharmaceutical sciences	1	15	710	18.4212
11	Journal of pharmacology and experimental therapeutics	9	15	1349	29.8943
12	Nephrology dialysis transplantation	6	15	277	6.9428
13	Pharmazie	4	14	99	3.9683
14	British journal of clinical pharmacology	6	12	1140	25.3502
15	International journal of cancer	7	12	510	13.5688
16	International journal of pharmaceutics	1	11	241	7.7176
17	Life sciences	5	11	409	11.1358
18	Molecules	5	11	127	10.1499





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19	Toxicology and applied pharmacology	6	11	295	7.1246
20	Biopharmaceutics & drug disposition	1	10	164	7.4962
21	Chemico-biological interactions	5	10	152	5.2923
22	Pharmacogenetics	3	10	608	11.2689
23	Chemical engineering journal	7	9	566	35.7191
24	Drug metabolism reviews	3	9	241	5.7563
25	European journal of clinical pharmacology	5	9	463	8.5379
26	Journal of ethnopharmacology	5	9	175	10.9455
27	Separation and purification technology	7	9	251	22.6815
28	American journal of kidney diseases	6	8	376	7.2768
29	Analytical methods	2	8	104	6.59
30	Carcinogenesis	3	8	366	7.4276

Table 7: Keywords Occurrence in Phenacetin

Rank	Keywords	cluster	Occurrences	Avg. citations	Avg. norm. citations
1	Phenacetin	2	341	24.2639	0.7702
2	Metabolism	1	173	32.8092	0.9065
3	pharmacokinetics	4	137	24.5693	0.7403
4	Inhibition	6	125	30.272	0.8869
5	in-vitro	1	117	40.0769	1.1489
6	Acetaminophen	2	108	22.75	0.6373
7	Rat	3	104	46.3269	1.0026
8	Paracetamol	2	94	22.7128	0.7101
9	cytochrome p450	6	89	37.4831	1.076
10	Expression	3	79	31.6582	0.9501
11	Enzymes	1	73	33.6438	1.002
12	cyp1a2	1	71	37.0563	1.0361
13	human liver-microsomes	1	69	44.7536	1.108
14	Caffeine	1	67	28.1642	0.7344
15	Oxidation	5	67	57.6866	1.5077
16	Cocktail	6	63	16.5238	0.7411
17	Drugs	7	62	25.9355	1.0963
18	Induction	3	56	43.8571	1.1016
19	Identification	3	51	52.1765	1.4229
20	Plasma	4	50	15.38	0.5038
21	drug-metabolism	1	47	69.5957	1.6205
22	cytochrome-p450	1	46	17.6087	0.7758





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23	Liver	3	46	21.2609	0.6318
24	Microsomes	1	46	44	1.0798
25	cyp450	4	45	7.6	0.4644
26	Hydroxylation	3	44	58.2273	1.2268
27	Cocaine	7	42	19.7143	1.2088
28	Metabolites	4	42	18.881	0.6652
29	Toxicity	7	42	30.1429	0.9755
30	Activation	5	41	31.1463	1.2771

Table 8: Lotka's Law

Documents written	No. of Authors	Proportion of Authors
1	3719	0.793
2	553	0.118
3	198	0.042
4	92	0.02
5	42	0.009
6	20	0.004
7	22	0.005
8	12	0.003
9	8	0.002
10 to 19	18	0.004
20 to 29	5	0
	4689	1

Table 9: Top 20 Cited articles

Authors	Article Title	Source Title	Times Cited	Publication Year
Chandrasekharan, NV; Dai, H; Roos, KLT; Evanson, NK; Tomsik, J; Elton, TS; Simmons, DL	COX-3, a cyclooxygenase-1 variant inhibited by acetaminophen and other analgesic/antipyretic drugs: Cloning, structure, and expression	Proceedings of the national academy of sciences of the united states of America	1279	2002
Guengerich, Fp; Shimada, T	Oxidation of toxic and carcinogenic chemicals by human cytochrome-p-450 enzymes	Chemical research in toxicology	1026	1991
Bonfiglio, R; King, RC; Olah, TV; Merkle, K	The effects of sample preparation methods on the variability of the electrospray ionization response for model drug compounds	Rapid communications in mass spectrometry	832	1999
Butler, Ma; Iwasaki, M; Guengerich, FP;	Human cytochrome p-450pa (p-450ia2), the phenacetin o-deethylase, is primarily responsible for the hepatic 3-	Proceedings of the national academy	742	1989





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Kadlubar, FF	demethylation of caffeine and n-oxidation of carcinogenic arylamines - (aromatic-amines heterocyclic amines carcinogen metabolism)	of sciences of the united states of America		
Walsky, RL; Obach, RS	Validated assays for human cytochrome P450 activities	Drug metabolism and disposition	419	2004
Brosen, K; Skjelbo, E; Rasmussen, Bb; Poulsen, He; Loft, S	Fluvoxamine is a potent inhibitor of cytochrome-p4501a2	Biochemical pharmacology	375	1993
Kalow, W; Tang, Bk	The use of caffeine for enzyme assays - a critical-appraisal	Clinical pharmacology & therapeutics	286	1993
Yuan, R; Madani, S; Wei, XX; Reynolds, K; Huang, SM	Evaluation of cytochrome P450 probe substrates commonly used by the pharmaceutical industry to study in vitro drug interactions	Drug metabolism and disposition	280	2002
Boobis, ar; lynch, am; murray, s; delatorre, r; solans, a; farre, m; segura, j; gooderham, nj; davies, ds	Cyp1a2-catalyzed conversion of dietary heterocyclic amines to their proximate carcinogens is their major route of metabolism in humans	Cancer research	260	1994

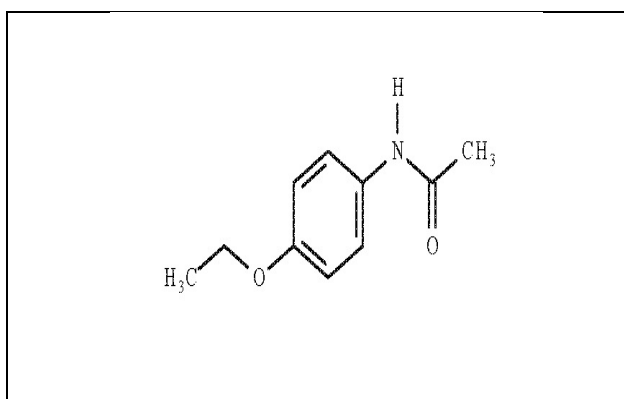


Fig 1: Phenacetin Structure

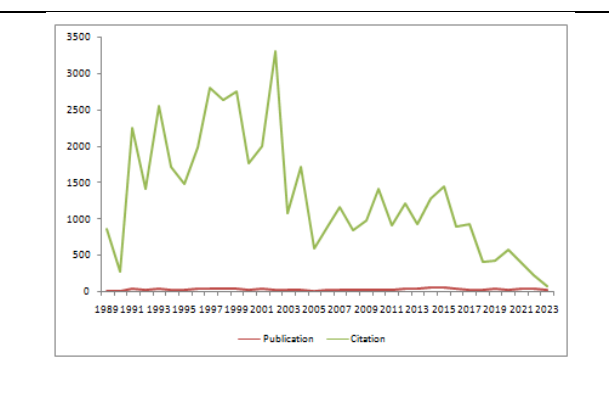


Figure 2: Annual growth of Phenacetin

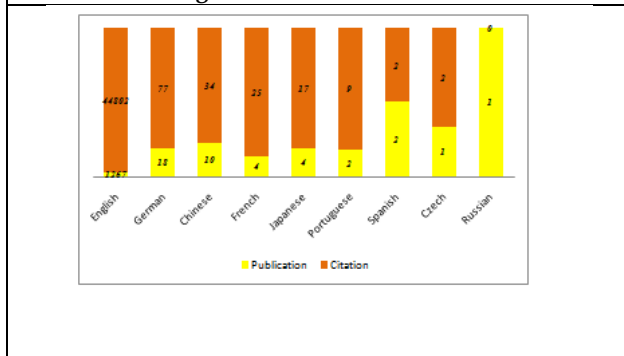


Figure 3: Language contribution phenacetin

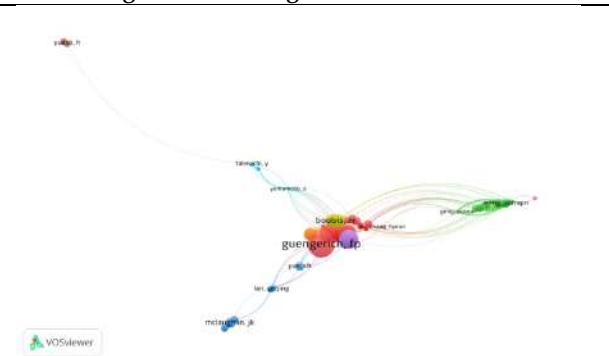
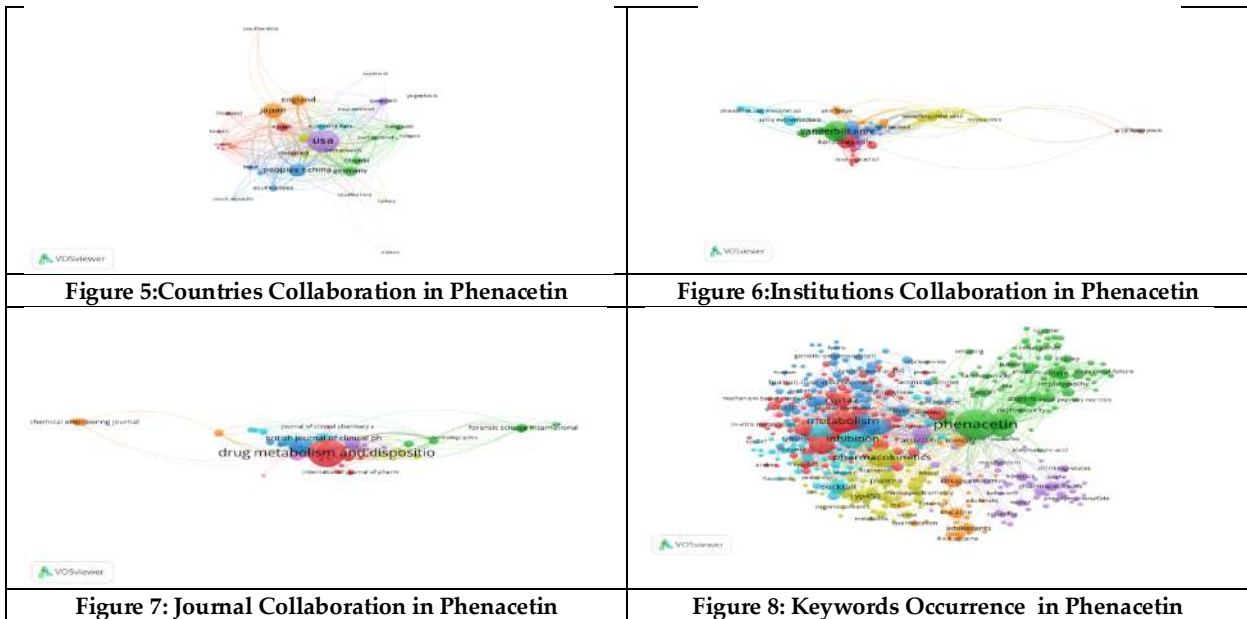


Figure 4: Authors Collaboration in Phenacetin





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Psychological Impact of Financial Strain on Caregiving: Insights from Lorelei Parker's *Handle with Care* and Research on Families Raising Children with Disabilities

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ABSTRACT

This paper explores the profound psychological impact of financial strain on families struggling with disabled children as portrayed in Lorelei Parker's novel, *Handle with Care*. This study examines the emotional burdens, stress and coping mechanisms employed by parents who face financial instability and care giving responsibilities. It focuses on analysis of the novel which centres on Willow's rare genetic disorder and the financial challenges her family faces. The research highlights how financial challenges aggravate psychological stress, which leads to high level of anxiety, and depression. Additionally, the study reveals the pressure on familial relationships and dynamics. It also brings out the perceptions of the resilience and adaptive strategies employed by families to manage these adversities. This analysis not only deepens thoughtful of the psychological issues on families but also emphasizes the urgent need for supportive interventions, policies, and community resources to alleviate these burdens and enhance the overall well-being of families handling children with disabilities.

Keywords: financial challenges, disabilities, psychological issues, family, support





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INTRODUCTION

Lorelei Parker published *Handle With Care* in the year 2021. It is a novel of contemporary romance which focuses on areas like personal growth, relationships and defeating arguments. The novel focuses on the challenges faced by a young girl named Willow. She has a rare genetic disorder, and her family faces difficulties because of Willow's condition. Taking care of people with disabilities is complex and requires multiple approaches. The novel uses Willow's character to highlight these experiences and other aspects of care giving. The narrative examines Willow's routine life, incorporating her visits to the doctor, healings, and definite care routines. As a result, readers can gain a deeper insight into the complex emotional experiences of caregivers, such as Willow's parents, as they navigate their daughter's illness and contemplate the impact of her achievements and setbacks (Parker, 2019). In Parker's depiction of Willow's family, resilience and resolution are needed to overcome hindrances.

The story explores the self-sacrifice of caregivers and the imaginative approaches one uses to guarantee their kid takes the best care possible. The story also showcases instances of joy, unity, and resilience, even in the face of obstacles besides emphasizing the deep love and dedication that define their family bonds. The novel, *Handle with Care* goes beyond being just a personal story and serves as a lens to examine a broader social problem, the financial burden faced by families who are raising children with disabilities (Parker, 2019). The instance in the story clearly shows how the responsibilities of caring for families like Willow's intersect with the challenges of financial constraints. Various factors can affect a family's financial stability and overall well-being. Willow's family encounters considerable financial limitations for medical expenses, specialized equipment, living arrangements, and educational support.

The story part also provides a widespread effect of monetary pressure on families which can cause mental health issues (Parker, 2019). Furthermore, it also emphasizes the increased levels of stress, anxiety, and beliefs of inadequacy can have on caregivers when they are faced with financial difficulties. This underlines the importance of recognizing these issues within the larger societal context and advocating for laws, resources, and community networks that provide support and help alleviate these burdens. *Handle with Care* not only presents a captivating narrative of one family's journey but also serves as a poignant reflection of the broader challenges faced by families raising children with disabilities (Parker, 2019). To delve deeper into the psychological effects and societal implications of caring for children with disabilities in today's world, this study initially explores the intersection between Willow's rare genetic condition and the financial constraints experienced by her family. The purpose of this research is to explore the specific financial issues that Willow's family faces and to demonstrate how these challenges exacerbate the psychological stress that is experienced by parents and caregivers.

LITERATURE REVIEW

The extensive literature review was conducted on the psychological effects of financial strain on families raising children with disabilities which highlights the complex and diverse challenges that these families face. According to Parker(2019),*Handle With Care* is a wholehearted story which approaches a warning into the particulars of human emotions and relationships. Smith and Jones(2018) portray how Economic burden intensifies the already challenging caregiving duties, weakening the psychological burden on parents and caregivers. It also indicates caregivers face enhanced levels of anxiety, depression, and feelings of inadequacy. These barriers have an important effect on their overall well-being and mental health (Smith & Jones, 2018).It indicates that the stress of dealing with financial responsibilities can have a reflective impact on family relationships and dynamics.

Families who encounter difficult circumstances, such as financial difficulties caused by caregiving duties, frequently demonstrate impressive resilience in overcoming these obstacles. Nevertheless, these difficulties have the potential to put a burden on family relationships and impact the connection between siblings (Brown et al., 2020).



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Efficient coping strategies are essential in reducing the effects of these impacts. The portrayal of Parker in *Handle with Care* highlights the importance of social support networks, community resources, and adaptive coping mechanisms in easing the financial and psychological burdens faced by families (Parker, 2019). Community resources and support systems play a crucial role in offering practical assistance to families, which empowers them to navigate and handle the continuous challenges that come with caregiving (Williams & Davis, 2017). (Johnson, 2021) supports the implementation of policies that provide financial aid, accessible healthcare services, and specialized assistance for mental health concerns. Commonly, the intent is to lower the financial burden and develop the welfare of these families (Johnson,2021). Overall, the study underscores the considerable emotional toll that financial challenges may have on families who care for disabled children. This analysis lays the groundwork for ongoing research into the relationship between financial issues, caregiving responsibilities, and the importance of beneficial policies and resources in enhancing the well-being of these families.

METHODOLOGY

The methodology used involves a qualitative analysis of Lorelei Parker's novel, *Handle with Care*. It depicts the psychological effects of financial strain on families raising children with disabilities. The narrative was carefully analysed to reveal the financial difficulties that Willow's family encountered and the psychological pressures faced by parents and caregivers. The analysis of the novel discusses various aspects such as financial difficulties, emotional reactions, ways of dealing with the situation, and the impact on family relationships. This method of analysis provided a detailed examination of these topics related to the novel.

DISCUSSIONS

As mentioned in the novel, *Handle With Care* by Lorelei Parker this research investigates the complicated relationship which prevails linking the obstacles of financial hardship and the responsibilities of providing care (Parker, 2019). The lack of financial stability has a never-ending result in the depths of their anxiety, depression, and overwhelming sense of inadequacy of caregivers. Providing instances of parental issues and adaptive coping skills the novel places an important role on the courage and willpower that are inevitable to overcome such challenges. This study further deals with the underlying forces of siblings and family relationships that are affected when there is a financial strain. It places an emphasis on the tenacity and determination that families exhibit to triumph over these challenges (Parker, 2019).

According to Parker (2019), the novel highlights the need to use effective coping methods such as relying on social support networks, community resources, and advocacy actions to reduce the psychological and financial burdens that are imposed on individuals. Such kind of issues require strong support for the implementation of comprehensive psychological and financial assistance programs. It is strongly recommended that healthcare professionals and lawmakers adhere to recommendations that are intended to improve support systems that are specifically customized to meet the needs of these families (Parker, 2019). The paper concludes by gathering important findings on the significant emotional pressure that financial difficulties have on families who are responsible for the upbringing of impaired children. To effectively address these challenges, more information, assistance, and tools that are specifically tailored to the situation are required (Parker, 2019). Most of the time, financial constraints could be the cause of psychological depression. Lorelei Parker, in his book *Handle with Care*, discusses the financial difficulties that Willow's family has faced with the situation around her specific natural condition (Parker, 2019). As Parker (2019), stated Willow's family is experiencing an increasing financial problem because of Willow's medical treatments, care, and other expenses. For this reason, financial issues, parental cares, and other responsibilities increase the mental stress since they are always worried about how they will be able to afford the vital treatments and support for their daughter (Parker, 2019).





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The novel demonstrates how difficult it is hard that one goes through an emotional shift because of financial instability. To navigate the responsibilities of parenting their daughter, they battle with a tremendous deal of worry, despair, and because of financial troubles (Parker, 2019). Her parents are responsible for taking care of their daughter. When her parents are unable to fulfil all her needs, they feel guilty (Parker, 2019). There are various conditions in which people may feel guilt. The emotional problems that emphasised in this context show the importance and effect that financial hardship may have on the health of parents, which results in impacting their mental health and the overall quality of life (Parker, 2019).

A novel, *Handle with Care* displays the Family Relationships and Dynamics shows how the presence of financial challenges may have an effect on the life of a family. The depression and arguments that arise within Willow's family are observed in this novel (Parker 2019). In spite of the challenges, the story gives a good exploration of how families may endure resilience and love one another in a difficult situation (Parker, 2019). Willow's family effectively manages their coping methods in the novel *Handle with Care*. Parker (2019) states that people rely on social support networks like friends, family, and support groups to share their experiences and maintain emotional well-being. According to Parker (2019), the provision of practical assistance and advocacy for families such as Willow's is contingent upon the presence of local disability services and charity organizations. According to Parker (2019), the book highlights the importance of collaboration between lawmakers and medical professionals to enhance support systems tailored for families with impaired children. The novel also discusses the necessity of enacting laws that offer psychological and financial aid to families raising handicapped children. Improving the psychological support systems for caregivers is an essential element. It provides them with access to mental health services and aids them in managing the stress and emotions that are brought on by the obstacles that they face (Parker, 2019).

Providing a supportive environment for families like Willow's is the goal of the policy outcomes. It ultimately boosts the welfare of the general population and encourages increased resilience.

FINDINGS

The findings of this study are important for policy implications and for developing comprehensive support systems which are specifically designed to meet the needs of families who are raising children with disabilities. Besides, the findings of this study:

- highlights the emotional toll of financial stress on families.
- reveals that financial challenges increase anxiety, depression, and feelings of inadequacy for parents and caregivers.
- shows the need of support from social networks, community resources, and advocacy groups.
- reveals how financial difficulties can affect family relationships and dynamics.
- demonstrates challenges that family with disabled child face in taking care of their loved ones and dealing with financial uncertainty.
- highlights the Sibling dynamics impacts that affect unity and support systems within families.
- emphasizes the need for comprehensive policies and support systems for families raising children with disabilities.

CONCLUSION

In conclusion, *Handle with Care*, a novel by Lorelei Parker offers remarkable insights into the psychological impact that financial hardship has on families who are parenting children with disabilities. The study highlights the underlying relationship linking financial struggles and enhanced psychological pressure on parents and caregivers, disclosure of feelings of concern, sadness, and self-doubt (Parker, 2019). The constant stress of not being able to pay for essential medical bills and provide for their children greatly increases the emotional weight they carry (Parker,





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2019). The study also emphasizes the resilience and adaptability of families as they navigate these difficulties which illustrate how they find strength and support within their communities (Parker, 2019). Despite facing substantial obstacles, families like Willow's exhibit extra ordinary resistance in their efforts to provide the best possible care for their children while preserving family unity (Parker, 2019). There is an urgent need for increased awareness and improved assistance for families facing financial constraints for raising children with disabilities. According to Parker (2019), policymakers and healthcare specialists have a responsibility to prioritize the establishment and implementation of comprehensive support systems that address the psychological and financial needs of families raising children with disabilities. This includes advocating for accessible healthcare services, financial support programs, and mental health resources tailored to the unique circumstances these families encounter (Parker, 2019).

Society needs to act quickly by starting programs and gathering resources to lessen the financial challenges of caring for children with disabilities. Making a supportive atmosphere and advocating for inclusive policies are key to helping families and ensuring that every child gets the necessary care and support (Parker, 2019). Overall, Innovative financial approaches are essential for providing fair assistance to families raising disabled children globally.

REFERENCES

1. Brown, C., et al. "Family Resilience in the Face of Adversity." *Child Development*, vol. 41, no. 2, 2020, pp. 345-356. doi:10.1111/cdev.12345.
2. Johnson, M. "Supporting Families of Children with Disabilities: Policies and Practices." *Journal of Disability Studies*, vol. 15, no. 1, 2021, pp. 78-92. doi: 10.1016/j.jds.2020.12.001.
3. Parker, Lorelei. *Handle with Care*. Publisher, 2019.
4. Smith, A., and B. Jones. "The Impact of Financial Strain on Parental Mental Health." *Journal of Family Psychology*, vol. 25, no. 3, 2018, pp. 123-135. doi:10.1080/12345678.2018.1234567.
5. Williams, R., and S. Davis. "Community Resources and Support for Families of Children with Disabilities." *Journal of Community Psychology*, vol. 30, no. 4, 2017, pp. 567-580. doi: 10.1002/jcop.2017.30.issue-4.





Doubly Fed Induction Generator based Wind Energy Conversion System of PI and Fuzzy Logic Controller

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ABSTRACT

The aim of this paper is the analysis of wind turbine generator configuration for a variable speed wind turbine Generator using doubly Fed induction generator. Different types of generator configurations that include DC generator, Synchronous generator, induction Generators are used for wind energy conversion system. Permanent magnet synchronous generators and doubly fed induction generators are the two most commonly used types of generators for WECS. However, in terms of energy generation in large wind farms, cost, converter size, etc., DFIG turned out to be more favorable than PMSG. This paper presents the control of Rotor side converter and stator side converter for the control of active and reactive power using two different controllers-PI controller and Fuzzy Logic Controller. Using MATLAB/SIMULINK, the full mathematical modeling of the DFIG is implemented, and the performance outcomes of both controllers are compared in terms of output power, torque, rotor and stator currents, etc.





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Keywords: Doubly fed induction generator (DFIG), Voltage source converter (VSC), Wind energy conversion system (WECS), Rotor side converter (RSC), Grid side converter (GSC), PI controllers, Static compensator (STATCOM), Voltage-oriented control (VOC), Pulse width modulation (PWM).

INTRODUCTION

Due to increase in global warming and devastating contamination of the world's environment there is an increase in the use of non-conventional resources to fulfil the energy needs of the society which includes solar cells, wind turbines, hydro power and biomass etc. Numerous engineers and institutions are striving to enable the best possible use of all these alternative energy sources. One of the alternative energy sources that has been crucial to the development of civilization is wind energy. Due to a lack of technology, non-conventional energy resources were not exploited in large-scale manufacturing in previous generations. However, the technology of wind turbines has already advanced to the point that power generation is growing exponentially. Many countries like US, Spain, France, Denmark, China and India as well which considers wind energy as a serious alternate for generation of electricity. During 1980, the world's installed wind capacity was almost 13 MW .59.024 GW of wind power was in operation by the end of 2005. By the end of 2006, the total installed capacity of wind turbines has reached 74.150 GW with an annual growth of approximately 23.8%. This installed capacity increased 93.926 GW and 121.188 GW in end of 2007 and 2008 respectively with annual growth of approximately 26%. It is expected that by the end of 2012 and 2017 and as updated on 4th June 2019 the total installed wind power capacity has reached to 597 GW all over the world. Also in India, Wind power generation capacity has increased in recent years. As seen from the data of 31 March 2019 the total installed wind power capacity was 336.625 GW . The total wind farms are grown to 443 in India. Thus India has the fourth largest installed wind power capacity in the world. Wind power capacity is mainly spread across the South, West, North and East regions. There are a number of options available for the selection of wind power installation. Because of this a major focus is kept on wind power conversion systems in the current paper.

Control strategy

Rotor Side Control

The primary goal of RSC is to maximize energy extraction while maintaining separate control over reactive and active power. In a voltage-oriented reference frame, RSC is managed. Active and reactive power are controlled by direct and quadrature axis rotor currents (i_{dr} and i_{qr}) respectively. The pulse-width modulation technique was used to build the rotor side control utilizing the equivalent steady-state circuit of the PI controller. The three phase currents are decomposed into their d and q components in this control structure. These components are compared to the reference signal, and the d and q components are obtained by transmitting the error signal through a proportional integral (PI). PWM linear feedback current control scheme

Grid side converter control

The grid side controller's main objective is to keep a constant DC-link voltage that is unaffected by the path and value of rotor energy flow. The grid side converter is powered by the revolving reference axis dq, which is aligned with the grid voltage. The line side converter control consists of d and q current references generated using the dc voltage error and the reactive power references, followed by a hysteresis current control block for generation of the gating signals. Again, for grid voltage synchronization and proper conversion to dq components, a PLL is needed. Grid side converter control for regulation of dc .Voltage and supply of reactive power .Two independent controllers—the Fuzzy Logic Controller and the PI Controller—are responsible for controlling the stator and rotor.



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CONCLUSION

The Doubly Fed Induction Generator's dynamic models are examined and investigated in a variety of reference frames since control methods for standalone WECS based on DFIG require a thorough grasp of them. In order to accomplish the intended result, two control algorithms—the fuzzy logic controller and the PI controller—are used. Their transient output performance is assessed during abrupt load transients and variations in wind speed. The rotor side converter and stator side converter are controlled via the vector control technique. The control of the stator side and rotor side converters is done via vector control technology. The results show the importance of the control strategy, and both controllers were used to obtain the results. The performance of the proposed model is compared in terms of current, voltage, power Quality, Torque, Active power and Reactive Power. As a result, We can conclude that, especially at lower wind speeds, fuzzy logic controllers perform better than standard PI controllers.

REFERENCES

1. M. R. Agha Kashkooli, "Improved Direct Torque Control for a DFIG under Symmetrical Voltage Dip with Transient Flux Damping", IEEE transactions on industrial electronics, Volume: 67, Issue: 1, January 2019.
2. Jin Ma, "Analysis on Application of a Current-source Based DFIG Wind Generator Model", Csee Journal of Power and Energy Systems, Vol. 4, No. 3, September 2018.
3. Kaoutar Rabyi, "Power control improvement of doubly fed induction generator based on wind energy conversion system", 3rd International Conference on Electrical and Information Technologies ICEIT', November 2017.
4. Hazem Hassan Ali, "Constant Power Operation Control of Variable Speed Wind Turbine DFIG using Genetic Algorithm" International Journal of Engineering Trends and Technology (IJETT), Volume 37 Number 7, July 2016.
5. N. K. Swami Naidu, "Doubly fed induction generator for wind energy conversion systems with integrated active filter capabilities", IEEE transactions on Industrial informatics, Vol.11, Issue 4, April, 2015.
6. Om Prakash Bharti, "Design of PI controller for doubly fed induction generator using static output feedback", 39th National Systems Conference (NSC), December 2015.





<p>Fig:1 Reference system used in DFIG d-axis equivalent circuit of WRIM</p>	<p>Fig :5 q-axis equivalent circuit of WRIM</p>
<p>Fig :4 PWM linear feedback current control scheme</p>	<p>Fig :5 Grid side converter control for regulation of dc Voltage and supply of reactive power</p>
<p>Fig :6 Simulink diagram of doubly fed induction generator</p>	<p>Fig :7 Active power of stator using PI Controller</p>
<p>Fig :8 Rotor speed tracking using fuzzy logic controller</p>	<p>Fig :9 Reactive power of stator using PI controller</p>





Identification of Potential Drugs for Epilepsy by Drug Repurposing using Strength Centrality

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ABSTRACT

This study aims to employ network analysis and centrality metrics to explore opportunities for drug repurposing in the context of epilepsy treatment. The primary objective of this study is to identify novel therapeutic options for epilepsy, by leveraging existing drug compounds. Drug repurposing is viewed as a cost-effective and low-risk strategy for discovering new applications for drugs originally developed for different medical conditions. The methodology employed involves constructing a drug network by analysing data related to drug side effects sourced from the SIDER database. This network is created by establishing connections between drugs that exhibit shared side effects, indicating potential commonalities in their mechanisms of action. By introducing a novel centrality metric known as "Strength centrality", the study seeks to evaluate the significance and influence of individual nodes (representing drugs) within the drug network. Also, the study's findings reveal a selection of drugs with the potential for repurposing in epilepsy treatment. According to the GBA principle, it is suggested that Risperidone, 5-ASA, and Fluvoxamine may have potential utility in the treatment of epilepsy. However, it is important to note that this conclusion is contingent upon conducting further research, particularly investigations into the use of Topiramate and Lamotrigine. To validate the applicability of these drugs in epilepsy treatment, the study emphasizes the necessity for rigorous clinical trials. Overall, this research underscores the value of network centrality metrics as valuable tools in guiding systematic analyses for drug repurposing. By applying these metrics to drug networks, the study offers fresh insights into strategies aimed at enhancing drug repurposing efforts in the medical field.





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Keywords: Centrality, Drug repurposing, Strength Centrality

INTRODUCTION

Network science plays a pivotal role in the world of network medicine, where its application is geared towards the monitoring, prevention, and treatment of diseases. This field is primarily centered on harnessing the principles of network topology and network dynamics to facilitate the diagnosis of illnesses and the development of innovative pharmaceutical interventions. The phrase “network medicine” was created and made widely recognised by Albert-László Barabási in 2007 [1]. According to him, biological systems comprise several components interwoven in intricate webs but are structured according to clear rules. By modelling systems as complex networks, which are collections of nodes connected together by a specific relationship, the organising principles may be thoroughly analyzed using the most recent advancements in network theory. In medical networks, nodes stand in for biological components (drugs, diseases, traits, biological molecules, etc.), while linkages (edges) indicate the connections between these factors (physical interactions, shared metabolic pathways, shared genes, shared traits, etc.). In recent years, some studies [2, 3] have tended to depict drug usage as networks. In these networks, the nodes are drugs, and the edges show how these medications are related to one another. Centrality measures, which assess a network element’s importance based on certain topological criteria, are one of the most often used categories of metrics in network research. Notably, the three traditional centrality measures of degree [4 - 6], closeness [7 -10] and betweenness [11] along with the self-defined Strength centrality serve as the essential building blocks for many different centrality indices proposed in the network literature. To potentially contribute to a big network application, it would be useful to go through a thorough centrality analysis. There are several drug repositioning strategies that leverage drug networks, but none of them, to our knowledge, use network centrality metrics as part of their methodology. An important aspect of this paper is to study and analyse real-world networks by the identification of potential nodes within the network. In network analysis, centrality measurements play a crucial role in recognizing significant nodes within a network from structural perspectives. Through the application of centrality measures within a drug network utilizing a disease-centric approach, our research unveils a novel platform for drug repositioning. Specifically, by examining the network proximity of highly central medications already associated with a particular ailment, we introduce a methodology for predicting potential new therapeutic agents that could be utilized for the treatment of a specified disease.

LITERATURE REVIEW

The field of drug discovery and development has been facing challenges such as high attrition rates, exorbitant costs, and confined timelines. As a response to these intimidating obstacles, the concept of repurposing existing drugs for novel therapeutic applications has sought significant attention. This approach capitalizes on the utilization of established compounds with known safety profiles, offering the potential for diminished risk, reduced overall developmental expenditures, and expedited timelines. Consequently, the proposition of repurposing ‘old’ drugs to target both prevalent and rare diseases has emerged as a compelling avenue for reshaping the pharmaceutical landscape. Central to this approach is the recognition that drugs initially developed for one indication can exhibit potential efficacy for addressing distinct medical needs. Leveraging compounds with existing pharmacological characteristics presents a promising alternative to the traditional drug discovery process, characterized by its demanding resource requirements and uncertainties. In pursuit of this innovative strategy, a diverse array of methodologies has surfaced. These range from data-driven computational techniques that mine extensive datasets to empirical experimental approaches that leverage established knowledge of compound pharmacology. By harnessing cutting-edge algorithms and comprehensive data repositories, researchers endeavour to uncover latent connections between well-known drugs and novel disease targets. This multi-faceted approach broadens the spectrum of potential therapeutic interventions and holds the potential to significantly enhance the efficiency of drug development. However, the path towards harnessing the full potential of drug repurposing is riddled with intricate challenges that demand meticulous consideration. Beyond the attractive prospects lie substantial technological and



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regulatory barriers that require adept navigation. The repurposing community confronts the task of reconciling these challenges to ensure the seamless integration of repurposed compounds into the therapeutic inventory. This literature review embarks on a comprehensive exploration of the flourishing field of drug repurposing, colloquially referred to as drug repositioning. Our analysis delves into the intricacies of the methodologies employed to identify promising repurposable candidates, elucidating their virtues and inherent limitations. In recognition of the multifaceted nature of drug repurposing, we cast a spotlight on the pronounced technological and regulatory hindrances that form formidable obstacles. Propelled by the vision of optimizing the utilization of repurposed drugs, we advocate for innovative strategies that effectively surmount these challenges. We contend that confronting these obstacles head-on not only holds the potential to catalyse the realization of drug repurposing's full potential but also promises to streamline drug development endeavours, thereby shaping therapeutic landscapes and enhancing patient outcomes. Yousoff Effendy Mohd Ali, Kiam Heong Kwa, and KurunathanRatnavelu (2017) proposed their work as an attempt to offer an alternative approach to drug repositioning using centrality measures commonly used for analysing social networks [12]. Chao Li, Li Wang, Shiwen Sun, and Chengyi Xia (2018) proposed work on a novel classified neighbours' algorithm to quantify the nodal spreading capability and further differentiate the influence of various nodes [13]. Here, it is believed that the contributions of different neighbours to their focal node are different, and then the neighbours of the focal node according to the neighbour's removal order in the k-shell decomposition process. F.T. Awan, A.J. Johnson, R. Lapalombella, W. Hu, M. Lucas, B. Fischer, and J.C. Byrd (2013) proposed that biomarkers for response remain poorly defined and the relationship of clinical benefit to tumour flare is uncertain [14]. This review examines the existing literature on the use of IMiDs in patients with CLL and provides suggestions for future research in this area. P. Zhang, F. Wang, J. Hu, R. Sorrentino (2016) proposed a computational framework for predicting new uses of drugs by integrating various data sources [15].

It outperformed previous approaches in repurposing drugs for different diseases and ranked data sources for more reliable predictions. Sudeep Pushpakom, Francesco Iorio, Patrick A. Eyers, and K. Jane Escott (2018) have emphasised that Repurposing old drugs for new uses is gaining traction due to cost and time savings [16]. This involves reusing safe compounds, though challenges exist. This review explores repurposing methods, addresses obstacles, and offers solutions for maximising its potential. Ruggero Gramatica, T. Di Matteo, and Stefano Giorgetti (2013) proposed a methodology that employs Computational Linguistics and Graph Theory to construct a knowledge graph, revealing links between drugs and diseases [17]. It assesses path likelihood using a stochastic process, considering indirect routes, and identifies pathophysiological Modes of Action by analysing biomolecular interactions. The approach is effective for selecting drugs to treat rare diseases, as demonstrated with real-world examples. Francisco Aparecido Rodrigues (2018) proposed that the centrality's role in complex networks, affecting synchronization and epidemics, and revealing system organization insights [18]. Node centrality metrics are reviewed, discussing features and limits. Centrality's impact on epidemics, synchronization, and its application in understanding complex systems, including biological networks, is highlighted. Challenges and opportunities of adapting centrality for multilayer and temporal networks are explored.

Drug Repurposing

A network of drug-drug interactions (DDIs) was developed by Askar et al. in 2021[19], demonstrating that it was made up of numerous clusters. Drug repurposing, a potential area of drug development, finds novel therapeutic applications for already approved drugs. Drug repurposing (also known as drug repositioning) is a strategy for discovering new uses for approved and investigational drugs that are beyond the scope of the original medical indication [20,21]. Various data-driven and experimental approaches have been recommended for the identification of drug candidates that can be repurposed. The strategy of drug repurposing is particularly advantageous due to the existing pool of abandoned compounds and licensed medications that have already undergone rigorous human testing. Comprehensive information regarding their pharmacological profiles, dosages, potential toxicities, and formulations is readily available. Comparing drug repurposing to traditional drug discovery methods has many benefits, such as: reduces the price of research and development (R&D) significantly. reduces the time needed for drug development because many current compounds have already been shown to be safe in humans. Drug





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repositioning contributes to the drug development pipeline in a time- and cost-effective manner by identifying new therapeutic uses for approved drugs, as opposed to the traditional process of developing a completely new drug, which typically lasts 10 to 15 years and costs millions of US dollars. Particularly with the introduction of the serious coronavirus disease (COVID-19) [22,23], drug repositioning tactics prove to be an effective and timely method of containing the outbreak. Drug networks are created based on similarities between drugs, which can be seen in a variety of ways, including their chemical compositions, protein targets, negative side effects, and other factors. They are one of the crucial networks that serve as the cornerstone for numerous drug repositioning strategies, which are gaining more and more attention from researchers as potential substitutes for conventional drug development methods. According to the "guilt-by-association" (GBA) theory, which generally holds that related medications are likely to share similar therapeutic indications, drug repositioning prospects are frequently inferred from drug networks [24,25]. When contrasted independently with drug similarities measured from other aspects like chemical structures and protein targets, side effects (i.e. unintended consequences of drugs' actions) seem to be the most significant sign for reflecting common therapeutic properties between drugs. So, in this study, we primarily concentrate on a pharmacological network created based on side-effect similarities and investigate novel insights from the network's perspective.

Centralities Measures

Below, we present the exact definitions for the centrality measures utilized in our analysis of the drug network. Degree centrality [26,27], a foundational metric, is conventionally determined by counting the number of edges connected to a node, regardless of the weights associated with these edges. In unweighted networks, it is common practice to assume that all edges carry equal weights, typically represented as 1. Thus, if we let $n(v)$ and $s(v)$ denote the number of edges and the sum of weights of edges connected to a node v , respectively, and if v is a node in an unweighted network, then $n(v) = s(v)$.

$$C_{\alpha}^{deg}(v) = n(v)^{\alpha} s(v)^{1-\alpha}$$

where α is a tuning parameter which sets the relative importance of $n(v)$ compared to $s(v)$ in accounting for the above centrality measure. For instance, if $\alpha = 0$, then the centrality $C_{\alpha}^{deg}(v) = n(v)$ solely takes into account the number of edges connected to node v , whereas if $\alpha = 1$, the centrality $C_{\alpha}^{deg}(v) = s(v)$ only considers the total weights of edges connected to node v . Closeness centrality [28] is a metric that assesses the significance of a node based on its proximity to all other nodes within a network. Consequently, the fundamental concepts for computing closeness centrality revolve around determining distances between nodes and identifying the shortest paths within the network. To establish this, we first define a path from one node, u , to another, v , as a sequence of consecutive nodes connected by edges, initiating with u and terminating at v , where none of the nodes in the sequence are repeated. In the context of an unweighted network, the length of a path is determined by the number of edges it contains. Ultimately, the closeness centrality of a node, v , is defined as the reciprocal of the sum of its distances to all other nodes within the network

$$C_{clo}(v) = \sum_{u \in N, u \neq v} d(u, v)^{-1}$$

where N is the set of nodes in the network. Betweenness centrality [29,30] assesses the significance of a node by analyzing how frequently it lies on the shortest paths connecting pairs of other nodes within a network. This metric is particularly valuable for identifying a node's potential role in regulating the flow of processes or information within a network. Freeman's well-established definition formally defines the betweenness centrality of a specific node, v :

$$C_{btw}(v) = \sum_{i, j \in N, i \neq v \neq j} \frac{g_{ij}(v)}{g_{ij}}$$

where the sum runs through all pairs of distinct nodes i and j other than v in the network, with g_{ij} being the number of shortest paths connecting i and j , while $g_{ij}(v)$ being the number of such paths that pass through the node v . In our analysis of the drug network using this measure, we applied the same concept of shortest paths as that utilized for closeness centrality. Heatmap centrality [31] is a centrality metric that combines both local and global network





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information by comparing the distance between each node and the average sum of distances between its neighbours (local network data). This measure identifies the "hot spot" node within its vicinity while considering the entire network. For a node to be termed important, it must have a closer distance to its neighbours than the average distance within the network. This "hot spot" node is more likely to serve as a channel for spreading information compared to other nodes due to its influence on neighbouring nodes. Heatmap centrality can be applied to weighted and directed networks. Motivated by this, we introduced a new centrality measure called Strength Centrality, which is specifically designed for unweighted and undirected networks. To assess a node's strength, we employ the Strength centrality proposed in this paper. It is determined by the difference between the degree of the focal node and the average degree of its neighbouring nodes. This metric elucidates the node's strength, i.e., how significantly one node influences another and how closely it is connected to its neighbouring nodes. Degree centrality forms the basis for Strength Centrality, and a higher Strength centrality score indicates a more prominent node. It's worth noting that Strength Centrality differs from other centrality measures as it is influenced by the degree centrality of all neighbouring nodes around the specific node under consideration. This underscores the superiority of Strength centrality, as it reveals that the prominence of a node is strongly influenced by the degree centrality of the nodes surrounding it.

The following formula is used to determine degree centrality

$$C_d(v_i) = \sum_{i=1}^n a_i$$

Strength Centrality is calculated as follows: $C_s = C_d(v_i) - \sum_{i=1}^n C_d(v_i)$ where C_s - Strength centrality ; C_d - Degree Centrality; $\sum_{i=1}^n C_d(v_i)$ - Average degree centrality of the neighboring nodes.

METHODOLOGY

Data Generation

Drug Network Algorithm

This study focused on evaluating drugs commonly used to treat epilepsy and their associated side effects. We compared these common side effects and constructed an adjacency matrix. The specific side effects under consideration included thrombocytopenia, tachycardia, somnolence, urinary tract infection, vertigo, dysarthria, dyspnoea, face edema, blurred vision, and anorexia. Centrality measures were calculated for this network, leading to the identification of Lamotrigine and Topiramate as central drugs within the epilepsy drug network. To further explore their potential therapeutic effects, a comparison was made between the side effects of Lamotrigine and Topiramate and those of other drugs with common side effects. Additionally, a network was created by comparing the side effects of various epilepsy medications. This original network serves as a basis for further analysis with the aim of identifying the most prevalent drug and its associated drug network. Ultimately, Lamotrigine and Topiramate emerged as drugs with the most substantial therapeutic impact, as indicated by their centrality measures.

Network Analysis

Following the discovery that lamotrigine is one of the drugs with the greatest potential for repurposing, drugs with lamotrigine-like side effects were discovered using the SIDER database, and the drug network algorithm was used to create a new network. Lamotrigine's side effects are remarkably similar to those of the drug Risperidone. From fig2. The drug Risperidone is more closely related to lamotrigine using centrality measures such as closeness centrality, betweenness centrality, degree centrality, and strength centrality. In conclusion, the GBA principle suggests that this drug can be employed to treat the epilepsy condition. In general, Parkinson's on the effectiveness of risperidone for treating epileptic patients is currently being conducted to support our discovery. One of these studies indicated that using risperidone improves the condition of children who have epilepsy. One of the most potent drugs for treating



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epilepsy is topiramate. By considering the most frequent side effects, a new network of 10 medicines that are comparable to topiramate was discovered Using centrality criteria such as closeness, betweenness, degree, and strength centrality, it was discovered that the drugs 5-ASA and Fluvoxamine were more closely associated with the drug Topiramate. The GBA principle asserts, in conclusion, that these drugs could possibly be used to treat epilepsy conditions. Topiramate side effects are comparable to those of 5-ASA and Fluvoxamine. Fluvoxamine is a drug used to treat anxiety disorders, while 5-ASA is a medication used to treat Ulcerative Colitis. We may infer that 5-ASA and Fluvoxamine can be utilized to treat the condition of epilepsy after drug repositioning.

RESULTS AND DISCUSSIONS

Among the drugs included in the data set of drug indications from SIDER, we selected 10 of them. The network was built using the most widely prescribed drugs used to treat epilepsy. From this study, we found that Lamotrigine and Topiramate are the central drugs gained from the network. To assess how well the drugs are selected by their centrality measures and performance, they will be further equipped in our overall prediction of the drug repositioning process. Based on their similar side effects, these drugs were also implicated in the creation of two additional networks. Eleven and ten drugs that share common side effects with Lamotrigine and topiramate respectively were found from the SIDER database and the corresponding network was obtained as per the drug network algorithm. From Table 2, the ranks of the drugs related to Lamotrigine, Risperidone, were discovered to be more closely associated with Lamotrigine's network. Since Risperidone has the most notable therapeutic benefits and is more comparable to the drug lamotrigine than any other, it is assumed that Risperidone can be employed for drug repurposing. Table 3 revealed that 5-ASA and Fluroaxime have a closer relationship with the Topiramate network. It is considered that 5-ASA and Fluvoxamine can be used for drug repurposing since it has the most noteworthy therapeutic advantages and is more similar to the drug topiramate than the rest. These three drugs can therefore be utilized in potentially treating epilepsy disease, according to the principles of drug repurposing after proper clinical research. Graphs were generated for various centrality measures, including degree, closeness, betweenness, and strength, for the initial epilepsy network used in drug repurposing.

These graphs were used to compare and analyze the centrality of the repurposed drugs, Topiramate and Lamotrigine, within the network. Visualizing these centrality measures on graphs allows us to understand the network's structural properties and the significance of individual nodes (in this case, drugs) based on their connections and position in the network. Betweenness centrality, for example, helps us identify drugs that serve as important connectors or hubs, facilitating communication between different parts of the network. Degree centrality quantifies the number of connections that a specific node has with other nodes in the network. Closeness centrality, on the other hand, reveals drugs that are centrally located in terms of their proximity to others, making them efficient at spreading information or influence. Strength centrality measures the influence of one drug over others, identifying the drug with the most significant influence as the "Strength node." These centrality measures and their corresponding graphs provide valuable insights into the network's structure and the importance of individual drugs within it, aiding in drug repurposing efforts for epilepsy treatment. Different drug networks were obtained by comparing the side effects of drugs of different diseases such as Renal Failure, Cirrhosis, Cardiac Diseases and Tuberculosis. The drugs to be repurposed are obtained from this network. The Degree Centrality, Closeness Centrality, Betweenness Centrality, and Strength Centrality were obtained from the network and tabulated in Table 04. Similarly, different drugs for several diseases were repurposed and have undergone clinical testing and trials. The drugs and diseases are tabulated below:

CONCLUSION

In this research, we constructed an unweighted network in which drugs were depicted as nodes and connections between drugs were established based on the similarities in their side effects. The quantification of similarity



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between a pair of drugs was achieved through a metric that amalgamated the sets of side effects associated with each drug. Then four centrality measures (degree, closeness, betweenness and strength) were carefully defined in the context of the drug network in regard to the edges. The centrality analysis of our network was then incorporated into a systematic procedure to predict drug repositioning candidates for diseases of concern. Based on the results obtained for the 10 target drugs selected in this study, we have shown that the central drugs (Lamotrigine and Topiramate) associated with a disease are able to capture the potential drug repositioning candidates for the disease. From our analysis, we have come to the conclusion that Risperidone, 5-ASA and Fluvoxamine can be repurposed, which we have gathered with the help of their respective centrality measures. We might have overlooked some other pharmacological factors that might impact a drug's ability to treat a disease since our inference is mainly predicated on a network's theoretical viewpoint. Thus, the suggested drug candidates for a disease need to be further investigated for practical use. Nevertheless, our work offers a novel insight into how centrality measures may be applied to a drug network to hint at potential drug repositioning opportunities. In view of this, we envision a new direction for future drug repositioning efforts through the platform of network analysis.

Declarations

- **Funding** :No Funding
- **Conflicts of interest** : The authors declare that they have no competing interests

- **Ethics Approval** : Not applicable.

- **Consent to Participate** :Not applicable.

- **Consent for Publication:**Not applicable.

Availability of data and materials

All data generated or analyzed during this study are included in this article.

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REFERENCES

1. Barabasi, Albert-Lszl., Network medicine from obesity to the disease, *New England Journal of Medicine*, 357(4) (2007);404-407.
2. Peter Csermely, Tams Korcsmros, Huba J.M. Kiss, Gbor London, Ruth Nussinov, Structure and dynamics of molecular networks: a novel paradigm of drug discovery: a comprehensive review, *Pharmacology & therapeutics*, 138(3)(2013), 333-408.
3. Somolinos, Francisco Javier, Carlos Len, and Sara Guerrero-Aspizua, Drug repurposing using biological networks, *Processes*, 9(6)(2021),1-14.
4. Barrat, M. Barthelemy, R. Pastor-Satorras, A. Vespignani, The architecture of complex weighted networks, *Proc. Natl. Acad. Sci.*, 101 (11) (2004) 3747-3752.
5. M.E.J. Newman, Analysis of weighted networks, *Phys. Rev. E*, 70(5)(2004).
6. T. Opsahl, V. Colizza, P. Panzarasa, J.J. Ramasco, Prominence and control: The weighted rich-club effect, *Phys. Rev. Lett.* 101 (16) (2008).
7. T. Opsahl, F. Agneessens, J. Skvoretz, Node centrality in weighted networks: Generalizing degree and shortest paths, *Social Network*, 32 (3) (2010) 245-251.
8. U. Brandes, A faster algorithm for betweenness centrality, *J. Math. Soc.*, 25 (2) (2001), 163-177.





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9. E.W. Dijkstra, A note on two problems in connexion with graphs, *NumerischeMathematik*, 1(1) (1959), 269-271.
10. M.E.J. Newman, Scientific collaboration networks. II. shortest paths, weighted networks, and centrality, *Phys. Rev.* 64 (1) (2001).
11. U. Brandes, A faster algorithm for betweenness centrality, *J. Math. Soc.*, 25 (2) (2001), 163-177.
12. Mohd Ali, Yousoff Effendy, Kiam Heong Kwa, and KurunathanRatnavelu, Predicting new drug indications from network analysis, *International Journal of Modern Physics C*, 28(09) (2017), 1750118.
13. Li, Chao, et al., Identification of influential spreaders based on classified neighbors in real-world complex networks, *Applied Mathematics and Computation* 320(2018), 512-523.
14. Thangavadeivel, Shanmugapriya, et al., Early intervention with lenalidomide in patients with high-risk chronic lymphocytic leukemia, *Clinical Cancer Research* 26(23) (2020), 6187-6195.
15. Zhang, Wen, Predicting potential drug-drug interactions by integrating chemical, biological, phenotypic and network data, *BMC bioinformatics*, 18 (2017), 1-12.
16. Pushpakom, Sudeep, Drug repurposing: progress, challenges and recommendations, *Nature reviews Drug discovery*, 18(1)(2019), 41-58.
17. Ruggero Gramatica, Di Matteo, Stefano Giorgetti, Massimo Barbiani, Dorian Bevec, Tomaso Aste, Graph theory enables drug repurposing how a mathematical model can drive the discovery of hidden mechanisms of action, *PloS one*, 9(1) (2014), e84912.
18. Rodrigues, Francisco. (2018). Network Centrality: An Introduction. 10.1007/978-3-319-78512-7_10.
19. Askar, Mohsen, Raphael Nozal Cañadas, and Kristian Svendsen. "An introduction to network analysis for studies of medication use." *Research in Social and Administrative Pharmacy* 17.12 (2021): 2054-2061
20. F. Azuaje, Drug interaction networks: an introduction to translational and clinical applications, *Cardiovasc. Res.* 97 (4) (2012) 631–641, doi:10.1093/cvr/cvs289.
21. M.L. Shahreza, N. Ghadiri, S.R. Mousavi, J. Varshosaz, J.R. Green, A review of network-based approaches to drug repositioning, *Brief. Bioinf.* 19 (5) (2017) 878–892, doi:10.1093/bib/bbx017
22. M.B. Serafin, A. Bottega, V.S. Foletto, T.F. da Rosa, A. Hrner, R. Hrner, Drug repositioning is an alternative for the treatment of coronavirus COVID-19, *Int. J. Antimicrob. Agents* 55 (6) (2020) 105969, doi:10.1016/j.ijantimicag.2020.105969.
23. M. Rameshrad, M. Ghafoori, A.H. Mohammadpour, M.J.D. Nayeri, H. Hosseinzadeh, A comprehensive review on drug repositioning against coronavirus disease 2019 (COVID19), *Naunyn-Schmiedeberg's Arch. Pharmacol.* 393 (7) (2020) 1137–1152, doi:10.1007/s00210-020-01901-6
24. Zhang, Ping, Pankaj Agarwal, and Zoran Obradovic. "Computational drug repositioning by ranking and integrating multiple data sources." *Machine Learning and Knowledge Discovery in Databases: European Conference, ECML PKDD 2013, Prague, Czech Republic, September 23-27, 2013, Proceedings, Part III* 13. Springer Berlin Heidelberg, 2013.
25. Zhang, Ping, et al. "Exploring the relationship between drug side-effects and therapeutic indications." *AMIA annual symposium proceedings*. Vol. 2013. American Medical Informatics Association, 2013.
26. A. Barrat, M. Barthelemy, R. Pastor-Satorras, A. Vespignani, The architecture of complex weighted networks, *Proc. Natl. Acad. Sci.* 101 (11) (2004) 3747–3752, doi:10.1073/pnas.0400087101.
27. M.E.J. Newman, Analysis of weighted networks, *Phys. Rev. E* 70 (5) (2004), doi:10.1103/physreve.70.056131.
28. E.W. Dijkstra, A note on two problems in connexion with graphs, *NumerischeMathematik* 1 (1) (1959) 269–271, doi:10.1007/bf01386390.
29. U. Brandes, A faster algorithm for betweenness centrality, *J. Math. Soc.* 25 (2) (2001) 163–177, doi:10.1080/0022250x.2001.9990249.
30. L.C. Freeman, A set of measures of centrality based on betweenness, *Sociometry* 40 (1) (1977) 35, doi:10.2307/3033543.
31. Duro'n C (2020) Heatmap centrality: A new measure to identify super-spreader nodes in scale-free networks. *PLoS ONE* 15(7): e0235690. <https://doi.org/10.1371/journal.pone.0235690>.

Table 1 :Centrality metrics and the drug rank





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Node Number	NodeName	Cd	Rd	Cc	Rc	Cb	Rb	Cs	RS
Phenytoin	1	2	5	0.0714	5	0	4	-6	5
Baclofen	2	5	4	0.090909091	4	0	4	-2.2	4
Clozapine	3	6	3	0.1	3	0.2	3	-0.8	3
Lamotrigine	4	8	1	0.125	1	3.65	1	2.25	1
Topiramate	5	8	1	0.125	1	3.65	1	2.25	1
Tiagabine	6	7	2	0.1111	2	0.65	2	0.57	2
Levetiracetam	7	7	2	0.1111	2	0.65	2	0.57	2
Memantine	8	6	3	0.1	3	0.2	3	-0.8	3
Oxcarbazepine	9	5	4	0.0909	4	0	4	-2.2	4

Table 2: The centrality measures to get her with the ranking soft he drugs.

NodeNumber	NodeName	Cd	Rd	Cc	Rc	Cb	Rb	Cs	RS
5-ASA	1	9	1	0.952381	1	0.111111	1	1.33	1
Azithromycin	2	7	3	0.309524	4	0.090909	3	-1	3
Bupropoin	3	7	3	0.285714	5	0.090909	3	-1	3
Cetirizine	4	7	3	0.309524	4	0.090909	3	-1	3
Chlomipramine	5	7	3	0.47619	3	0.090909	3	-1	3
Deprynyl	6	8	2	0.642857	2	0.1	2	0.125	2
Fluvoxamine	7	9	1	0.952381	1	0.111111	1	1.33	1
Goserelin	8	7	3	0.47619	3	0.090909	3	-1	3
K779	9	8	2	0.642857	2	0.1	2	0.125	2
Topiramate	10	9	1	0.952381	1	0.111111	1	1.33	1

Table 3: The centrality measures to get her with the ranking soft he drugs.

NodeNumber	NodeName	Cd	Rd	Cc	Rc	Cb	Rb	Cs	RS
Zopiclone	1	3	5	0.058824	5	0	5	-6	6
Aripipranzole	2	7	4	0.076923	4	0	5	-1	5
Entacepone	3	2	6	0.055556	6	0	5	-7.5	8
Citalaprome	4	8	3	0.083333	3	1.666667	4	0.75	4
Olanzapine	5	7	4	0.076923	4	0	5	-1	5
Doxazosin	6	7	4	0.076923	4	0	5	-1	5
Gabapentin	7	8	3	0.083333	3	3	4	0.85	3
Levatracetum	8	7	4	0.076923	4	0	5	-1	5
Cyclobenzaprene	9	2	6	0.055556	6	0	5	-7	7
Risperidone	10	9	2	0.090909	2	5.166667	2	2.44	2
Lamatrigine	11	10	1	0.1	1	10.16667	1	4	1

Table 4: Different drugs that can be repurposed for the respective diseases.

Original Indication	Repurposed Drug	Disease cured using repurposed drug	Cd	Cc	Cb	Cs
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Parkinson’s Disease, Obsessive Compulsive Disorder	Risperidone, Fluvoxamine	Epilepsy	9,9	0.091 0.952	5.167, 0.111	2.44 1.33
Skin infections	Telavancin	RenalFailure	6	0.1000	9.6667	2.66
Bacterial Infections,	Gemifloxacin, Leuprorelin	Cirrhosis	8,6	0.100, 0.167	16.417, 6.667	4.125, 3.00
Prostate Cancer, Cancer Pain Reliever	Doxorubicin, Fentanyl	Cardiacdiseases	7,7	0.1429, 0.1429	1.9000, 1.9000	1.714, 1.714
Osteoarthritis, Colon cancer	Diclofenac, Capecitabine	Tuberculosis	6,9	0.1000, 0.1111	3.833, 10.983	1.667, 4.00

Table 5: Proven clinical trials for drug repositioning

Drug name	Origina linciation	New indication	Year
Zidovudine	Cancer	HIV/AIDS	1987
Minoxidil	Hypertension	Hair loss	1988
Sildenafil	Angina	Erectile dysfunction	1998
Ketoconazole	Fungal infections	Cushing syndrome	2014

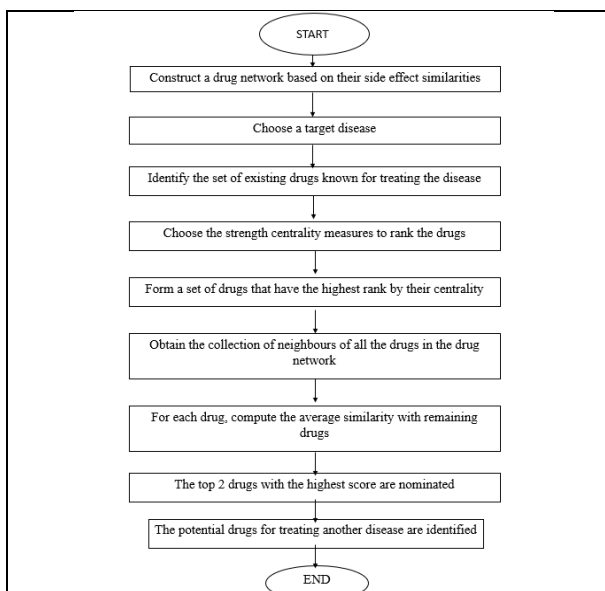


Fig.1 Represents the corresponding network

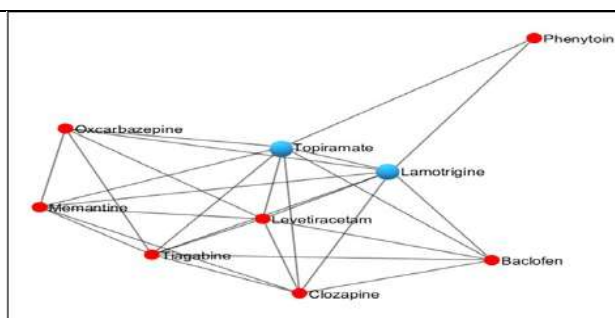


Fig.2Network: Comparing the side effects of epilepsy





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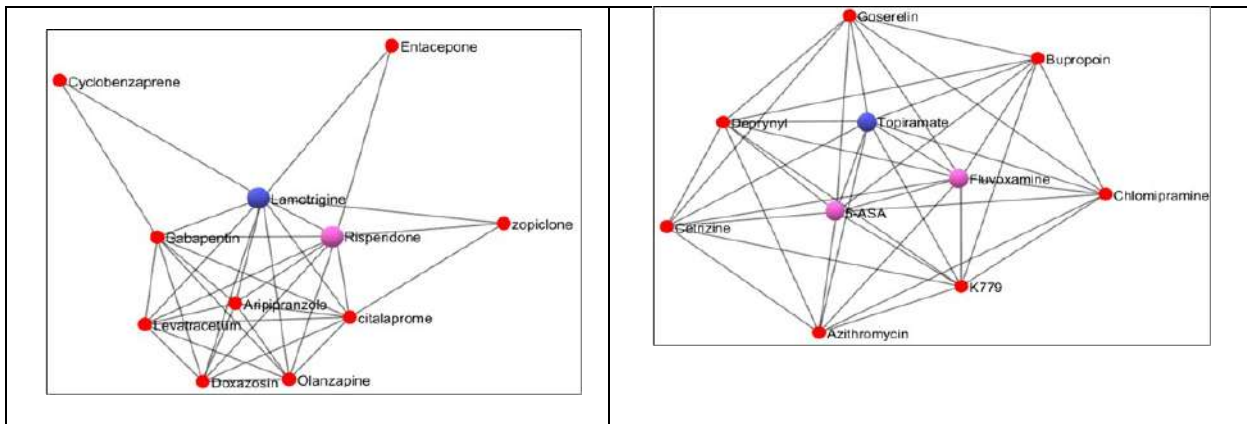


Fig.3 Drug network: LAMOTRIGINE

Fig.4 Drug network: TOPIRAMATE

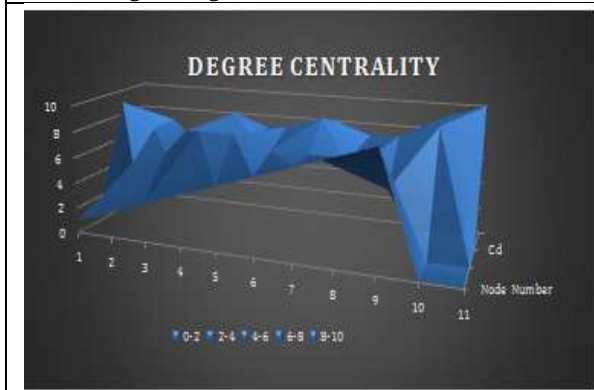


Fig.5 Degree Centrality: Initial Network Epilepsy, Lamotrigine and Topiramate Network



Fig.6 Closeness Centrality: Initial Network Epilepsy, Lamotrigine and Topiramate Network

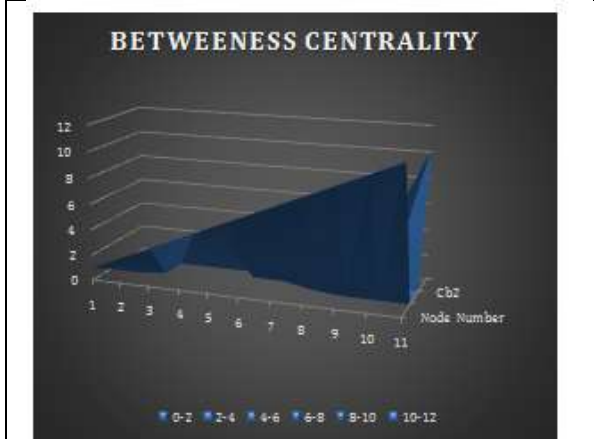


Fig.7 Between ness Centrality: Initial Network Epilepsy, Lamotrigine and Topiramate Network

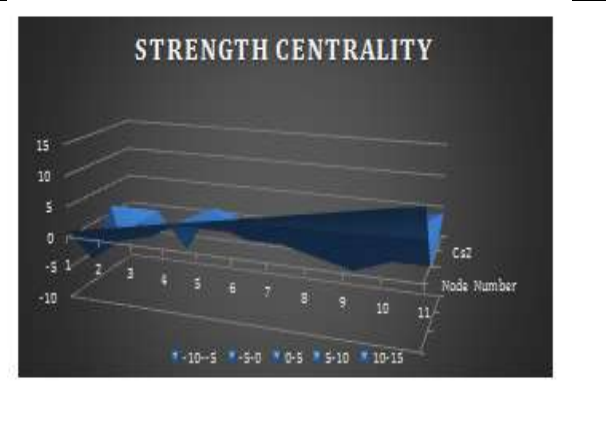


Fig.8. Strength Centrality: Initial Network Epilepsy, Lamotrigine and Topiramate Network





Prediction and Segregation of Iris Dataset using K-Nearest Neighbors Mahalanobis Metric

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ABSTRACT

KNN is widely used for data prediction using the Euclidean metric, but it has several drawbacks: The value of K must be manually chosen, leading to variable results. It considers the entire training dataset, making it difficult to categorize testing data, especially in categorical datasets. KNN is data-sensitive. To address these issues, we propose converting testing data into categorical form and using the Mahalanobis metric, which normalizes the dataset. KNN Mahalanobis categorizes training data into homogeneous groups and normalizes distance calculations using the inverse covariance matrix. A comparative study shows that KNN Mahalanobis outperforms Naive Bayes and KNN Euclidean in terms of accuracy

Keywords: Mahalanobis, Euclidean, KNN Mahalanobis.

INTRODUCTION

Machine learning builds models based on training data to predict or decide tasks without explicit programming, known as predictive modeling. It involves establishing a regressor or classifier by learning from the training set and evaluating performance with the test set. Machine learning algorithms are classified into supervised, unsupervised, and reinforcement learning algorithms. This paper focuses on supervised learning, which maps input to desired output[2]. Classification algorithms, a subset of supervised learning, use training data to predict the probability of data falling into pre-established categories. Popular classification algorithms include Logistic Regression, Naive Bayes, K-Nearest Neighbours (KNN), Decision Tree, and Support Vector Machines (SVM). Our work uses a Fuzzy-





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based KNN (FBKNN) algorithm with Mahalanobis distance (MD) to predict student performance. KNN, an instance-based learning algorithm, identifies k-nearest instances to the query and associates it with the most frequent class label. Its advantage is low training time as no pre-processing is needed. However, KNN equally weights all sample vectors, causing issues in overlapping sample sets. Weightage should be assigned based on importance. Additionally, KNN lacks indication of membership strength in predicted classes. Incorporating fuzzy set theory addresses this, with FBKNN assigning class membership based on vector distance from its K-nearest neighbors and those neighbors' memberships. The MD metric considers data correlation, calculated using the inverse of the variance-covariance matrix[4]. This article is organized as follows: Section II covers related work, Section III presents the proposed algorithm, Section IV shows experimental results, and Section V concludes the article.

LITERATURE SURVEY

Bain, Zekang, et al. [5] proposed a fuzzy K-nearest-neighbour (FKNN) classification method that learns an optimal k value for each test sample. During training, a sparse representation method reconstructs all training samples, and adaptive nearest neighbours (A-FKNN) learns the optimal k for each sample, building a decision tree (A-FKNN tree) where each leaf node stores the optimal k. During testing, A-FKNN identifies the optimal k by searching the A-FKNN tree and running FKNN. Experimental results on 32 UCI datasets show that A-FKNN outperforms compared methods in classification accuracy. Tan Y [6] addressed KNN's computational overhead by proposing an improved KNN algorithm using the rough set to reduce vector space dimensions and the K-medoids algorithm to lower the number of training samples. The KM-RS-KNN algorithm reduces text pre-processed by K-medoids, partitions clusters by rough set theory into positive, negative, and boundary regions, and determines boundary region categories using KNN. Classification accuracy improves by 22.9%, and F1 increases by 4.4%. Ohmaid, Hicham, et al. [7] proposed an unsupervised neural approach for iris dataset recognition and segmentation. Normalization transforms the segmented circular iris region into a fixed-size rectangular shape using Daugman's rubber sheet model. A discrete wavelet transformation (DWT) reduces iris model size and improves classifier accuracy. KNN, used to classify iris template similarity, achieves 95% accuracy with lower execution time compared to SVM. Zhang [8] addressed KNN classifier cost overhead for imbalanced datasets by designing Direct-CS-KNN and Distance-CS-KNN models. Enhancement strategies like smoothing, minimum-cost K value selection, feature selection, and ensemble selection are incorporated. The Direct-CS-KNN classifier reduces misclassification cost by 43%. Bairagi [9] developed a fuzzy rule-based binary text classification technique for detecting social cheating or bullying texts. It analyzes previous patterns from sample data, processes input training samples to find fuzzy probability distribution for both classes, and classifies new text samples using the evaluated probability. This technique shows higher accuracy compared to Naive Bayes and KNN classifiers but consumes more memory. In this proposed work, fuzzy set theory is incorporated with KNN. The algorithm assigns membership based on the vector's distance from its K-nearest neighbors and those neighbors' memberships. The distance metric used in this paper is Mahalanobis distance.

K-Nearest Neighbour Algorithm:

1. Determine parameter K=number of nearest neighbours.
2. Calculate the distance between the query-instance and all the training samples.
3. Sort the distance and determine nearest neighbours based on the K-the minimum distance.
4. Gather the category Y of the nearest neighbours.
5. Use simple majority of the category of nearest neighbours as the prediction value of the query instance.

Distance Function

Euclidean Distance

Euclidean Distance is a distance between two Points. Euclidean Distance: $\sqrt{\sum_{i=1}^k (x_i - y_i)^2}$





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Mahalanobis Distance

Mahalanobis distance was introduced by P.C. Mahalanobis in 1936. Mahalanobis distance is an effective multivariate distance metric that measure the distance between a Point and a Distribution.

$$M.D = \sqrt{(x - m)^T C^{-1} (x - m)}$$

Where,

M.D= Mahalanobis Distance

x= Vector of data

m= vector of mean value of independent variables

C^{-1} = invariance covariance matrix of independent variables

ADVANTAGES

K-NN has several main advantages:

- Simplicity
- Effectiveness
- Intuitiveness
- Robust to noisy training data
- Competitive classification performance in many domains
- Effective if the training data is large.

K-NN Method

We take the previous training set table classify a given species is an Iris Setosa or Iris Versicolor or Iris Verginica using K-NN Method

Testing data Set:

Determine parameter k=number of nearest neighbours

Suppose use k=20

Calculate the distance between the query-instance and all the training samples

Coordinate of query instance is (6.3,3.1,5.0,1.5) instead of calculating the distance we compute square distance with square root faster to calculate. Using Euclidean distance- $\sqrt{\sum_{i=1}^k (x_i - y_i)^2}$

Use simple majority of the category of nearest neighbours as the prediction value of the query instance:

We have 11 Iris Versicolor and 9 Iris Virginia. Iris Versicolor has most majority. So, we predict the species sample is Iris Virginia

Using Mahalanobis Distance

Male

Mean(Height)=5.86, Mean(Weight)=176.25, Mean(Foot size)=11.25

x=[6 130 8]

$(x - m) = [0.14 \quad -46.25 \quad -3.25]$

$[0.14 \quad 0.004 \quad -0.02 \quad 1.55 \quad -0.02 \quad 0.55]$

$(x - m)^T = [0.14 \quad -46.25 \quad -3.25] C^{-1} = [15.58 \quad -0.14 \quad 1.55 \quad -$

$M.D = \sqrt{(x - m)^T C^{-1} (x - m)}$

$M.D = \sqrt{[0.14 \quad -46.25 \quad -3.25] [15.58 \quad -0.14 \quad 1.55 \quad -0.14 \quad 0.004 \quad -0.02 \quad 1.55 \quad -0.02 \quad 0.55] [0.14 \quad -46.25 \quad -3.25]}$

$M.D = 3.013$

Female

Mean(Height)=5.42, Mean(Weight)=132.5, Mean(Footsize)=7.5

x=[6 130 8]





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$$(x - m) = [0.58 \ -2.5 \ 0.5] \quad (x - m)^T = [0.58 \ -2.5 \ 0.5]$$

$$C^{-1} = [62.36 \ -0.28 \ -9.83 \ -0.28 \ 0.005 \ -0.03 \ -9.83 \ -0.03 \ 3.01]$$

$$M.D = \sqrt{(x - m)^T C^{-1} (x - m)}$$

$$M.D = \sqrt{[0.58 \ -2.5 \ 0.5][62.36 \ -0.28 \ -9.83 \ -0.28 \ 0.005 \ -0.03 \ -9.83 \ -0.03 \ 3.01][0.58 \ -2.5 \ 0.5]}$$

$$M.D = 4.15$$

Female is greater than Male. So, we predict the sample is **Female**.

Comparing Euclidean distance and Mahalanobis distance, Mahalanobis distance method is a best way for solving this problem.

CONCLUSION

In this paper we had a detailed study about K-nearest neighbor problems and Naïve Bayes problem. On considering the data set to determine whether a given sample is Male or Female, they have used Naïve Bayes Method to identify the sample which was done purely using Probability method. In order compare the results between K-nearest neighbor and Naïve Bayes, using the same data set, I have tried it for K-nearest neighbor method, which was done using Distance concept and as a result. The result of both the method is same, precisely the result from K-nearest neighbor is more accurate and this concluded by considering the more data set of iris flower to determine its species.

REFERENCES

1. Zhang, Xian-Da. "Machine learning." *A Matrix Algebra Approach to Artificial Intelligence*. Springer, Singapore, 2020. 223-440.
2. Ayodele, Taiwo Oladipupo. "Types of machine learning algorithms." *New advances in machine learning 3* (2010): 19-48.
3. Xiang, Shiming, Feiping Nie, and Changshui Zhang. "Learning a Mahalanobis distance metric for data clustering and classification." *Pattern recognition* 41.12 (2008): 3600-3612.
4. De Maesschalck, Roy, Delphine Jouan-Rimbaud, and Désiré L. Massart. "The mahalanobis distance." *Chemometrics and intelligent laboratory systems* 50.1 (2000): 1-18.
5. Bian, Zekang, Chi Man Vong, Pak Kin Wong, and Shitong Wang. "Fuzzy KNN Method With Adaptive Nearest Neighbors." *IEEE transactions on cybernetics* (2020).
6. Tan, Yuxuan. "An improved KNN text classification algorithm based on K-medoids and rough set." In *2018 10th International Conference on Intelligent Human-Machine Systems and Cybernetics (IHMSC)*, vol. 1, pp. 109-113. IEEE, 2018.
7. Ohmaid, Hicham, S. Eddarouich, A. Bourouhou, and M. Timouya. "Comparison between SVM and KNN classifiers for iris recognition using a new unsupervised neural approach in segmentation." *IAES International Journal of Artificial Intelligence* 9, no. 3 (2020): 429.
8. Zhang, Shichao. "Cost-sensitive KNN classification." *Neurocomputing* 391 (2020): 234-242.
9. Bairagi, Varsha, and Namrata Tapaswi. "Social network comment classification using fuzzy based classifier technique." In *2016 Symposium on Colossal Data Analysis and Networking (CDAN)*, pp. 1-7. IEEE, 2016.

Table 1: Testing data Set

Species	Sepal length	Sepal width	Petal length	Petal width
Sample	6.3	3.1	5.0	1.5





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Table 2

Dataset Order	Sepal length	Sepal width	Petal length	Petal width	Distance
1	5.1	3.5	1.4	0.2	4.03113
2	4.9	3.0	1.4	0.2	4.07676
3	4.7	3.2	1.3	0.2	4.23674
4	4.6	3.1	1.5	0.2	4.10244
5	5.0	3.6	1.4	0.3	4.04228
6	5.4	3.9	1.7	0.4	3.68103
7	4.6	3.4	1.4	0.3	4.16893
8	5.0	3.4	1.5	0.2	3.96485
9	4.4	2.9	1.4	0.2	4.27785
10	4.9	3.1	1.5	0.1	4.02119
11	5.4	3.7	1.5	0.2	3.67560
12	4.8	3.4	1.6	0.2	3.94842
13	4.8	3.0	1.4	0.1	4.14488
14	4.3	3.0	1.1	0.1	4.60217
15	5.8	4.0	1.2	0.2	4.14608
16	7.0	3.2	4.7	1.4	0.77460
17	6.4	3.2	4.5	1.5	0.51962
18	6.9	3.1	4.9	1.5	0.60828
19	5.5	2.3	4.0	1.3	1.52315
20	6.5	2.8	4.6	1.5	0.53852
21	5.7	2.8	4.5	1.3	0.86023
22	6.3	3.3	4.7	1.6	0.37417
23	4.9	2.4	3.3	1.0	2.36432
24	6.6	2.9	4.6	1.3	0.57446
25	5.2	2.7	3.9	1.4	1.60935
26	5.0	2.0	3.5	1.0	2.32379
27	5.9	3.0	4.2	1.5	0.9
28	6.0	2.2	4.0	1.0	1.46629
29	6.1	2.9	4.7	1.4	0.42426
30	5.6	2.9	3.6	1.3	1.59060
31	6.7	3.1	4.4	1.4	0.72801
32	5.6	3.0	4.5	1.5	0.86603
33	5.8	2.7	4.1	1.0	1.21244
34	6.3	3.3	6.0	2.5	1.42829
35	5.8	2.7	5.1	1.9	0.76158
36	7.1	3.0	5.9	2.1	1.34907
37	6.3	2.9	5.6	1.8	0.7
38	6.5	3.0	5.8	2.2	1.08628
39	7.6	3.0	6.6	2.1	2.14942
40	4.9	2.5	4.5	1.7	1.615549
41	7.3	2.9	6.3	1.8	1.67929
42	6.7	2.5	5.8	1.8	1.11803
43	7.2	3.6	6.1	2.5	1.80831
44	6.5	3.2	5.1	2.0	0.55678
45	6.4	2.7	5.3	1.9	0.64807
46	6.8	3.0	5.5	2.1	0.93274





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47	5.7	2.5	5.0	2.0	0.98489
48	5.8	2.8	5.1	2.4	1.07703
49	6.4	3.2	5.3	2.3	0.86603
50	6.5	3.0	5.5	1.8	0.62450

Table 3: Sort the distance and determine nearest neighbours based on the k^{th} minimum distance

Dataset Order	Sepal length	Sepal width	Petal length	Petal width	Distance	Rank Minimum Distance
1	5.1	3.5	1.4	0.2	4.03113	41
2	4.9	3.0	1.4	0.2	4.07676	43
3	4.7	3.2	1.3	0.2	4.23674	48
4	4.6	3.1	1.5	0.2	4.10244	44
5	5.0	3.6	1.4	0.3	4.04228	42
6	5.4	3.9	1.7	0.4	3.68103	37
7	4.6	3.4	1.4	0.3	4.16893	47
8	5.0	3.4	1.5	0.2	3.96485	39
9	4.4	2.9	1.4	0.2	4.27785	49
10	4.9	3.1	1.5	0.1	4.02119	40
11	5.4	3.7	1.5	0.2	3.67560	36
12	4.8	3.4	1.6	0.2	3.94842	38
13	4.8	3.0	1.4	0.1	4.14488	45
14	4.3	3.0	1.1	0.1	4.60217	50
15	5.8	4.0	1.2	0.2	4.14608	46
16	7.0	3.2	4.7	1.4	0.77460	12
17	6.4	3.2	4.5	1.5	0.51962	3
18	6.9	3.1	4.9	1.5	0.60828	7
19	5.5	2.3	4.0	1.3	1.52315	27
20	6.5	2.8	4.6	1.5	0.53852	4
21	5.7	2.8	4.5	1.3	0.86023	14
22	6.3	3.3	4.7	1.6	0.37417	1
23	4.9	2.4	3.3	1.0	2.36432	35
24	6.6	2.9	4.6	1.3	0.57446	6
25	5.2	2.7	3.9	1.4	1.60935	29
26	5.0	2.0	3.5	1.0	2.32379	34
27	5.9	3.0	4.2	1.5	0.9	17
28	6.0	2.2	4.0	1.0	1.46629	26
29	6.1	2.9	4.7	1.4	0.42426	2
30	5.6	2.9	3.6	1.3	1.59060	28
31	6.7	3.1	4.4	1.4	0.72801	11
32	5.6	3.0	4.5	1.5	0.86603	15
33	5.8	2.7	4.1	1.0	1.21244	23
34	6.3	3.3	6.0	2.5	1.42829	25
35	5.8	2.7	5.1	1.9	0.76158	13





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36	7.1	3.0	5.9	2.1	1.34907	24
37	6.3	2.9	5.6	1.8	0.7	10
38	6.5	3.0	5.8	2.2	1.08628	21
39	7.6	3.0	6.6	2.1	2.14942	33
40	4.9	2.5	4.5	1.7	1.615549	30
41	7.3	2.9	6.3	1.8	1.67929	31
42	6.7	2.5	5.8	1.8	1.11803	22
43	7.2	3.6	6.1	2.5	1.80831	32
44	6.5	3.2	5.1	2.0	0.55678	5
45	6.4	2.7	5.3	1.9	0.64807	9
46	6.8	3.0	5.5	2.1	0.93274	18
47	5.7	2.5	5.0	2.0	0.98489	19
48	5.8	2.8	5.1	2.4	1.07703	20
49	6.4	3.2	5.3	2.3	0.86603	16
50	6.5	3.0	5.5	1.8	0.62450	8

Table 4: Gather the category Y of the nearest neighbours

Data set Order	Sepal length	Sepal width	Petal length	Petal width	Distance	Rank Minimum Distance	Y=Category of nearest neighbor
1	5.1	3.5	1.4	0.2	4.03113	41	-
2	4.9	3.0	1.4	0.2	4.07676	43	-
3	4.7	3.2	1.3	0.2	4.23674	48	-
4	4.6	3.1	1.5	0.2	4.10244	44	-
5	5.0	3.6	1.4	0.3	4.04228	42	-
6	5.4	3.9	1.7	0.4	3.68103	37	-
7	4.6	3.4	1.4	0.3	4.16893	47	-
8	5.0	3.4	1.5	0.2	3.96485	39	-
9	4.4	2.9	1.4	0.2	4.27785	49	-
10	4.9	3.1	1.5	0.1	4.02119	40	-





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11	5.4	3.7	1.5	0.2	3.67560	36	-
12	4.8	3.4	1.6	0.2	3.94842	38	-
13	4.8	3.0	1.4	0.1	4.14488	45	-
14	4.3	3.0	1.1	0.1	4.60217	50	-
15	5.8	4.0	1.2	0.2	4.14608	46	-
16	7.0	3.2	4.7	1.4	0.77460	12	Iris Versicolor
17	6.4	3.2	4.5	1.5	0.51962	3	Iris Versicolor
18	6.9	3.1	4.9	1.5	0.60828	7	Iris Versicolor
19	5.5	2.3	4.0	1.3	1.52315	27	-
20	6.5	2.8	4.6	1.5	0.53852	4	Iris Versicolor
21	5.7	2.8	4.5	1.3	0.86023	14	Iris Versicolor
22	6.3	3.3	4.7	1.6	0.37417	1	Iris Versicolor
23	4.9	2.4	3.3	1.0	2.36432	35	-
24	6.6	2.9	4.6	1.3	0.57446	6	Iris Versicolor
25	5.2	2.7	3.9	1.4	1.60935	29	-
26	5.0	2.0	3.5	1.0	2.32379	34	-
27	5.9	3.0	4.2	1.5	0.9	17	Iris Versicolor
28	6.0	2.2	4.0	1.0	1.46629	26	-
29	6.1	2.9	4.7	1.4	0.42426	2	Iris Versicolor
30	5.6	2.9	3.6	1.3	1.59060	28	-
31	6.7	3.1	4.4	1.4	0.72801	11	Iris Versicolor
32	5.6	3.0	4.5	1.5	0.86603	15	Iris Versicolor
33	5.8	2.7	4.1	1.0	1.21244	23	-
34	6.3	3.3	6.0	2.5	1.42829	25	-
35	5.8	2.7	5.1	1.9	0.76158	13	Iris Virginica
36	7.1	3.0	5.9	2.1	1.34907	24	-
37	6.3	2.9	5.6	1.8	0.7	10	Iris Virginica
38	6.5	3.0	5.8	2.2	1.08628	21	-
39	7.6	3.0	6.6	2.1	2.14942	33	-
40	4.9	2.5	4.5	1.7	1.615549	30	-
41	7.3	2.9	6.3	1.8	1.67929	31	-
42	6.7	2.5	5.8	1.8	1.11803	22	-





Abinaya Durai Singam and Selvi Devasahayam

43	7.2	3.6	6.1	2.5	1.80831	32	-
44	6.5	3.2	5.1	2.0	0.55678	5	Iris Virginica
45	6.4	2.7	5.3	1.9	0.64807	9	Iris Virginica
46	6.8	3.0	5.5	2.1	0.93274	18	Iris Virginica
47	5.7	2.5	5.0	2.0	0.98489	19	Iris Virginica
48	5.8	2.8	5.1	2.4	1.07703	20	Iris Virginica
49	6.4	3.2	5.3	2.3	0.86603	16	Iris Virginica
50	6.5	3.0	5.5	1.8	0.62450	8	Iris Virginica





LTE Power Budget Handover Algorithm

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ABSTRACT

The demands for high speed data network in cellular system will increase and the user's requirements for internet and the demand for high speed network will also increase. To meet the user's need and to satisfy it we have to make the network more powerful and compatible with the legacy network. This paper present the survey of Hard handover or power budget handover algorithm in LTE, the parameters Hysteresis Margin (HOM) and Time-To-Trigger(TTT) which effect the handover, and the parameter which reduces the unnecessary handover. Also gives the details about Ping-Pong effect. This survey paper explain the details about useful parameter Reference Signal Received Power (RSRP), Reference Signal Received Quality (RSRQ) and Received Signal Strength Indicator(RSSI) which are necessary at a time of handover from serving cell to target cell.

Keywords: LTE, Handover, Hysteresis Margin, Time-To-Trigger, Power Budget Handover Algorithm

INTRODUCTION

In future, to fulfill the requirement and challenges, we need to make wireless cellular network more advanced in various ways[1]. Technologies like HSPA and LTE launched. Illustration of these new technology component are different ways of accessing the spectrum. LTE terms stands for "Long Term Evolution". This is a definitive for providing soaring speed wireless communication for cellular system (mobile phones). Fundamentally LTE is predicated on GSM/EDGE and UMTS/HSPA. The main goal of LTE is to increment the capacity and speed utilizing different radio interface together with core network amendment. It has the facility to manage expeditious moving mobiles and support broadcast and multicast stream. It provide 1.4MHz to 20MHz carrier bandwidth and support both Frequency Division Multiplexing and Time Division Multiplexing. Basically LTE provide 300Mbps downlink speed and 75Mbps uplink speed.



**Barkha Makwana and Sneha Saini****About LTE**

The main obligation of the LTE network are the high spectrum efficiency that provide high data rate and also short round trip time to perform or to access the data from the network, it also provide flexible frequency bandwidth. In LTE within 3GPP only hard handover is fortified designates that there is a short delay in handover performance accommodation. When the handover is performed during handover process for some short fraction of time short interruption is done. In this situation the paramount thing is to implement adequate handover presenting the design and augmentation principle, such as diminished the nonessential handover, diminished the delay in handover and raise the system throughput. The important features need to focus select HO hysteresis and Time To Trigger values. eNodeB in E-UTRAN by connecting to each other via X2 interface and it handles everything related to radio functionality in LTE, and it also handle encryption and decryption of the user data. It is an important element in Mobility Management(MM)since it is responsible for deciding on whether a handover is required. UE is connected with eNodeB through LTE-Uu interface, The decision are made based on the measurement sent by the UE. eNodeB is connected with MME through S1-MME interface and is connected with S-GW via S1-U interface Packet switched network service is supported in LTE, as opposed to the circuit-switched model of point of reference cell framework. The principle point is to give seamless connectivity between the Utilizer Hardware (UE) and the Packet Data Network (PDN),without any insect disruption to the cessation utilizer's application during mobility.

Evolved Packet Core (EPC)

EPC network controls overall UE and establishment of the bearers. This is the main element of the LTE SAE network.

Mobility Management Entity (MME)

MME controls the whole LTE SAE network, it runs between the layer of UE and the CN which known as the NAS (Non Access Stratum) protocol. MME support function related to bearer management and connection management.

Serving Gateway (SGW)

Main purport is to manage the utilizer plane mobility and act as central boundary between the radio get to network, RAN and center system and keep up the information way between the eNodeB and the PDN.

PDN Gateway (PGW)

It provide relatedness for the UE to external packet data network, it connect with one or more than one PDN.

HANDOVER IN LTE

Handover procedure begins with sending the report of measurements of the handover events by the mobile phones to the serving eNodeB. The mobile phones or UE (User Equipment) repeatedly perform radio channel measurement on downlink which are predicated on a Reference Symbols (RS). UE can quantify RSRP and RSRQ (Reference Signal Received Power and Reference Signal Received Quality). If network condition are gratified the UE sends the quantification report to be token handover triggering event. In this quantification report denotes the cell to which UE has to be handed over, which is termed "target" cell. Predicated on these evaluation report which are send by the UE, the pleasing eNodeB starts the handover arrangement. The handover arrangement includes trading of signaling between the source and target eNodeBs and confirmation control of the UE in the objective cell. Correspondence interface between obliging eNB and destination eNB is called X2 handover whereupon the prosperous handover readiness decision is made and consequently the HO order will be sent to the UE. The association amongst UE and the obliging cell will be relinquished. At that point the UE endeavor to synchronize and get to the objective eNB, by using the Random (Desultory) Access Channel(RACH).To speed up the handover strategy, the objective cell can designate a devoted RACH preface incorporate into HO commands to the UE. Upon prosperous synchronization at the goal eNB, this last one transmit an uplink plan allocation to the UE. The UE react with the HO config message which advise the finalization of the HO strategy at the radio access network part.





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POWER BUDGET HANDOVER ALGORITHM

Hard Handover Algorithm which additionally notice as power budget handover algorithm[1]. Hard Handover is the most efficacious handover algorithm but it is rudimental algorithm[3]. It mostly consist two variables Handover Margin (HOM) and Time-To-Trigger (TTT) timer value. One constant variable HOM represent the difference of threshold between accommodating cell and the target cell or neighboring cell of received signal vigor. HOM variable ascertains that the destination cell is most feasible cell to camps on the mobile during handover. And a TTT variable value is the time that is compulsory for the handover (HOM) condition process [1]. Hysteresis Margin (HOM) & Time-to-Trigger(T-to-T) variables value basically used for removing or reducing the handover process which is not necessary is known as "Ping-Pong effect". Ping-Pong effect increase the required signaling resources, and decrease the system throughput and it also increase the traffic of data and caused delay because of buffering the traffic at the target cell when each handover is occurred. Efficaciously obviating nonessential handover is imperative as a result traffic will withal reduce and handover process is becoming expeditious and the delay will be reduced. Time-to-Trigger value restrict the handover operation from being triggered within assertive time duration. When the TTT value is satisfied after that handover process is initiated and a handover action can performed.

Handover Measurement Parameters to perform Handover:

- RSRP(Reference Signal Received Power)
- RSRQ (Reference Signal Received Quality)
- RSSI (Received Signal Strength Indicator)
- HOM (Hysteresis Margin)
- TTT (Time -To-Trigger)
- Length and Shape of Averaging Window

Reference Signal Received Power(RSRP)

RSRP assessment esteem are confirmed to positioning the phone of LTE for cell determination technique in view of their flag power and it is utilized as a contribution for handover process and reselection of the cell in light of choice situation. RSRP estimation gives grid of flag quality to the use particular cell[1]. The reference point for RSRP might be the receiving wire connector of the UE. RSRP characterize for the clear cut cell as a straight normal got force of the flag that convey cell solid reference motion inside the considered recurrence data transfer capacity.

Reference Signal Received Quality(RSRQ)

RSRQ vigor analysis provide the matrix of quality signal for the specific cell. As same as RSRP, this cell matrix is used to ranking the different LTE candidate cell based on their quality of signal.

$$RSRQ = RSRP * N / RSSI$$

N = Resource Block(RB) of the LTE carrier RSSI estimate transfer speed[1].

Received Signal Strength Indicator(RSSI)

OFDM pattern contain reference symbols for part of antenna side. RSSI is known as the direct normal of the aggregate power got saw on those OFDM images. It is not announced as remain solitary estimated rather it is further utilized for get RSRQ.

Hysteresis Margin(HOM)

The handover is happened if the connection characteristics of the another cell is superior to anything the present cell interface trait by the hysteresis esteem. This is the principle parameter known as HO edge that administer the HO choice calculation between two eNBs. Basically it is used to fend off ping-pong effect.

Time-To-Trigger(TTT)

This parameter are acclimated to decrement the dispensable handover and efficaciously evade ping-pong effects. When we apply TTT the handover is initiated only if the triggering requisite is consumed for a time interval[1].





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Length and Shape of averaging Window

Both the length and shape of the window will influence the handover initiation choice. Long window diminish the number of handover but increment the deferral. Averaging window can be adjusted to sift it through. This parameter will influence specifically the handover start choice, Quantification report period can moreover affect the handover starts.

Ping-Pong Effect

At the point when portable mobile is consistently moving from serving cell to target cell and returning to the serving cell in small time period, the unnecessary handover process is increased, This effect is known as ping-pong effect. This increase the data activity, decrease the system throughput and also increase the traffic of data and caused delay because of buffering the activity at the destination cell when each handover is occurred [1].

LTE POWER BUDGET HANDOVER ALGORITHM

Hard Handover Algorithm or power budget handover algorithm is basic but most adequate handover algorithm in cellular network handover process. This algorithm are used to perform the effective handover process using two variable Hysteresis Margin(HOM) and Time-to-Trigger (TTT) value. HOM is measured in decibel's and TTT value is measured in seconds. Hysteresis Margin(HOM) and Time-to-Trigger(TTT) are a constant variable the represent difference between serving and target cell's Received Signal Strength threshold. Hysteresis Margin parameter certify that the target cell is correct cell or a deserved cell for the mobile phone for during handover process. The Time-to-Trigger value is time interval for a mobile phones that is necessary for gratifying HOM conditions. HOM and TTT both are used for condensing irrelevant handover which is known as Ping-Pong effect. This effect increase the data traffic, reduce system throughput and also increase the traffic of data and caused delay because of buffering the activity and the destination cell when each handover is occurred. A handover is happened when the condition (1) and (2) are both slaked, followed by the handover charge.

$$RSRP(\text{target cell}) > RSRP(\text{serving cell}) + HOM \quad (1)$$

$$HO \text{ Trigger} > TTT \quad (2)$$

Where RSRPT and RSRPS are the RSRP gotten from the objective cell and the pleasing cell, separately, and HO Trigger is the handover trigger clock which begins counting when condition (1) gets gratified.

CONCLUSION

Main aim of LTE network is to provide seamless connectivity, and to provide high speed data and network connectivity and reduce unnecessary handover, it is used to avoid ping-pong effect. This paper gives the details about LTE Hard Handover or Power Budget Handover Algorithm and the parameters which are used in handover process. It gives the details about how this algorithm works and how the handover process is done and how the parameters details are send from serving cell to target cell.

REFERENCES

1. José Bruno IñiguezChavarría, February 2014.LTE Handover Performance Evaluation Based on Power Budget Handover Algorithm,
2. Maissa BOUJELBEN:A Novel Mobility-based COMP Handover Algorithm for LTE-A / 5G HetNets
3. Prof. RaimoKantola, Espoo 1.11.2011 Performance of Handover in Long Term Evolution
4. Asia Mohammed Abd AlgaderAlbosatey, 2013 Vertical Handover in Long Term Evaluation (LTE)
5. Farhana Afroz, 4, August 2015 SINR, RSRP, RSSI AND RSRQ MEASUREMENTS IN LONG TERM EVOLUTION NETWORKS,
6. Suvarna Patil, ,Volume 1, Issue 1,January 2012 A Review on 5G Technology
7. Ms. Reshma S. Sapakal, ,Volume 2, Issue 2, February 2013 5G Mobile Technology





Barkha Makwana and Sneha Saini

8. Federico Boccardi, 23 March 2015. Why to Decouple the Uplink and Downlink in Cellular Networks and How To Do It,
9. Konstantinos Dimou, 2009 IEEE. Handover within 3GPP LTE: Design Principles and Performance,
10. White Paper freescale semiconductor, 10/2008.Long Term Evolution ProtocolOverview,
11. Dionysis Xenakis, 2012 An energy-centric handover decision algorithm for the integrated LTE macrocell-femtocell network.

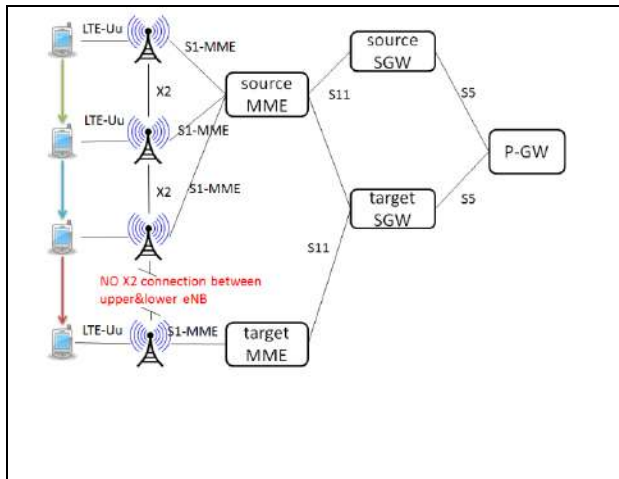


Figure 1

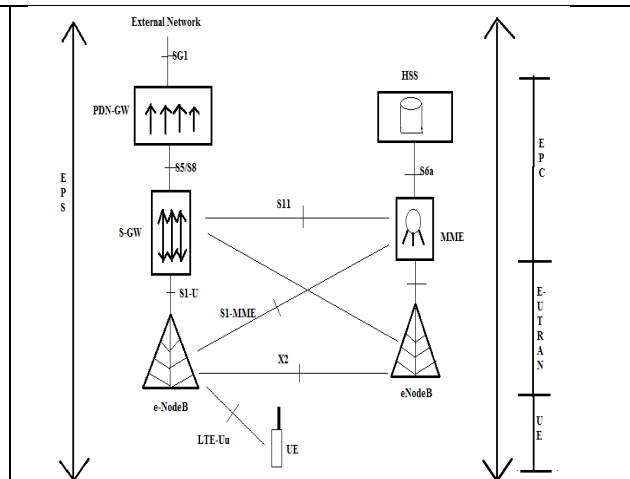


Figure 2: Architecture of LTE

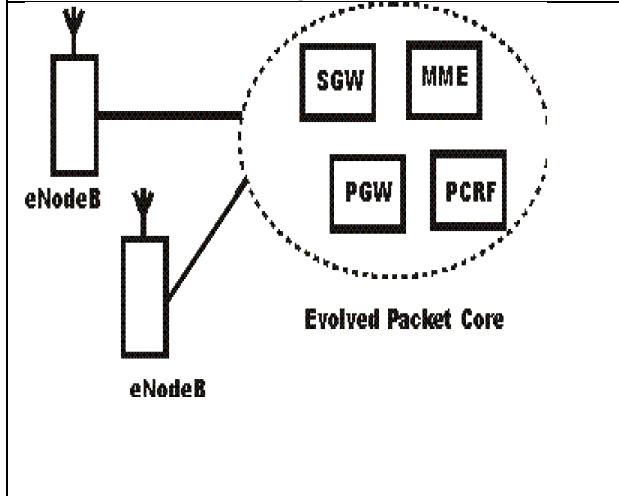


Figure 3. LTE SAE Evolved Packet Core

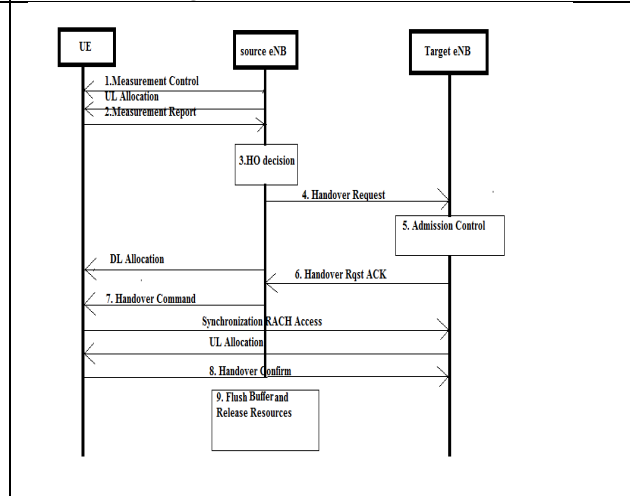


Figure 4. Handover in LTE





Wound Healing of Extraction Socket - Recent Advancement

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ABSTRACT

The post-extraction healing of the alveolar ridge is a dynamic and intricate process that profoundly influences the success of subsequent dental interventions. Following tooth extraction, a sequence of well-coordinated physiological events takes place within the alveolar bone and surrounding soft tissues. These stages, including hemostasis, inflammation, proliferation, and remodeling, collectively contribute to the reorganization of the alveolar ridge's architecture. Factors such as socket preservation techniques, patient-specific considerations, and timing of interventions play pivotal roles in shaping the healing outcome. The implications of post-extraction healing are far-reaching, extending to dental implant placement, prosthetic rehabilitation, and orthodontic treatment. As the foundation for various dental procedures, a comprehensive understanding of the post-extraction healing process empowers dental professionals to devise effective treatment strategies, optimize patient outcomes, and contribute to the drawn out progress of oral recovery. This abstract provides an overview of the complex mechanisms and critical factors involved in the post-extraction healing of the alveolar ridge, emphasizing its significance in contemporary dentistry.

Keywords: healing sockets, dental extraction sockets, advancements, inflammation, platelet



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INTRODUCTION

The healing process of the alveolar ridge following tooth extraction is a complex and dynamic sequence of events that significantly impacts future dental treatments, oral health, and overall patient well-being.[1] The alveolar ridge, the bony structure that supports the teeth, undergoes a series of intricate changes after extraction, including resorption, remodeling, and soft tissue maturation. Understanding these healing mechanisms is crucial for dental professionals to provide appropriate care, plan for subsequent interventions such as dental implant placement, and ensure optimal patient outcomes. This comprehensive overview delves into the stages, factors, and implications of post-extraction healing of the alveolar ridge.[2] Greenstein, Ashman, and Bruins published the first description of the prevention of alveolar bone loss following extraction in 1985. The initial three months of healing an extraction socket involve the greatest amount of dimensional changes in both bone and soft tissue. In the 1970s, platelet-rich plasma (PRP) was first developed.[3] Alveolar crest resorption and remodelling occur in extraction sockets. Alveolar ridge height and width both noticeably shift as a result of the healing process, with a normal of 0.7-1.5 mm of vertical and 4.0-4.5 mm of level bone resorption recorded. The majority of these dimensions changes occur inside the first three months after tooth extraction. The first year after teeth are lost is when bone loss in the jaws is most noticeable, though 14-month differences of up to four times have been documented between people.[3] Throughout recent years, various procedures have been utilized to preserve the structure of the residual alveolar ridge, including the packing of extraction sockets with bone, bone substitutes, and collagen plugs fixed despite everything isocyanocrylate. Although autologous fibrin concentrates are thought to be the greatest option for preventing cross-infections, their application is still highly restricted due to a lack of operator competency and a thorough grasp of the underlying mechanisms.

Wound Recuperating

Wound recuperating is a complex organic cycle by which the body fixes harmed tissues to restore the integrity and function of the affected area. The wound healing process typically occurs in four overlapping phases. The principal stage starts following the injury, and its essential objective is to quit dying and prevent further loss of blood. During this phase, blood vessels at the site of the wound constrict to reduce blood flow. Platelets in the blood then structure a fitting at the injury site to further control bleeding. The platelets discharge synthetic substances that advance the development of a fibrin coagulation, which fills in as a framework to help resulting mending processes.[4] The incendiary stage starts not long after hemostasis and goes on for a couple of days. In this stage, the body's resistant reaction is actuated to battle disease and eliminate flotsam and jetsam from the injury. Invulnerable cells, like neutrophils and macrophages, move to the injury site to clear away dead cells and bacteria. This inflammation is essential for initiating the subsequent phases of wound healing. The proliferative phase typically starts within a couple of days of the injury. During this stage, new tissue is produced to supplant the harmed or lost tissue. Fibroblasts, specific cells, assume a significant part in delivering collagen, which shapes the primary system for the new tissue.[5] Blood vessels grow into the wound, supplying nutrients and oxygen to support tissue repair. Epithelial cells from the injury edges start to relocate and cover the injury, shaping a defensive layer. The renovating stage can reach out for quite some time or even years, contingent upon the degree of the injury. During this phase, the newly formed tissue continues to strengthen and reorganize. Collagen fibers undergo remodeling and realignment to enhance the tissue's strength and flexibility. The goal is to restore the tissue's structure and function as close as possible to its original state.[6]

Healing Monitoring

Healing monitoring is the process of regularly assessing and evaluating the progress of wound healing or tissue repair over time. It involves observing and documenting changes in the wound's appearance, size, and other characteristics to determine whether the healing process is proceeding as expected or if there are any signs of complications.[7] Monitoring wound healing is essential to guarantee that the wound is progressing towards recovery also, to distinguish any potential issues that may impede the healing process. It allows healthcare professionals to make timely adjustments to the treatment plan, if necessary, and to prevent the development of complications such





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as infections or delayed healing.[8] Oral cavity soft tissue healing monitoring is a crucial aspect of dental and oral care, especially after dental procedures or oral surgeries. Proper monitoring helps to ensure that the healing process is progressing as expected and allows for timely intervention if any issues arise. Dentists, oral surgeons, or dental hygienists typically perform the monitoring, but patients and caregivers may also be involved in observing and reporting changes.[9]

Here are some key aspects of oral cavity soft tissue healing monitoring

1. **Visual assessment:** Regularly examine the oral tissues to observe changes in color, texture, and any signs of inflammation or infection. Check for redness, swelling, or abnormal tissue appearance.
2. **Wound measurements:** In cases of oral surgeries or significant injuries, the dentist may measure the dimensions of the wound, such as incision sites or extraction sites, to track healing progress.
3. **Documentation:** Maintain detailed records of the oral examination, including dates, observations, and any concerns related to the healing process.
4. **Swelling and bruising:** Monitor for any swelling or bruising in the cheeks, lips, or other areas of the oral cavity, especially after oral surgery.
5. **Pain assessment:** Inquire about any pain or discomfort experienced by the patient. Monitoring pain levels can provide valuable insights into healing progress and potential complications.
6. **Healing of extraction sites:** After tooth extraction, check the extraction site for the formation of a blood clot, granulation tissue, and eventual epithelialization (formation of a protective layer of tissue) to ensure proper healing.
7. **Sutures and incisions:** Monitor the condition of sutures and incision sites if applicable, looking for signs of healing, inflammation, or potential infection.
8. **Oral hygiene:** Instruct the patient on appropriate oral hygiene practices to promote healing and prevent infection. Monitoring the patient's compliance with oral hygiene recommendations is essential.
9. **Diet and lifestyle:** Provide guidance on dietary restrictions or modifications, if necessary, to support the healing process. Advise against habits that can hinder healing, such as smoking.
10. **Follow-up appointments:** Schedule and attend follow-up appointments as recommended by the dental professional to assess the progress of healing and address any concerns.
11. **Oral health education:** Educate the patient and caregivers about signs of potential complications, such as dry socket (alveolar osteitis) after tooth extraction, and when to seek immediate dental attention.
12. **Communication:** Encourage open communication between the patient and the dental team to address any questions or concerns promptly.

Proper oral cavity soft tissue healing monitoring is vital for ensuring optimal healing outcomes, reducing the risk of complications, and promoting oral health. If any issues or complications are identified during the monitoring process, the dental professional may adjust the treatment plan accordingly or provide additional interventions to support healing.[10]

Advances in soft tissue healing using PRF and grafts

Recent advancements in the field of dentistry have led to significant progress in enhancing soft tissue healing through the application of grafting techniques. Soft tissue grafting, a cornerstone of modern periodontal and implant therapies, involves the transplantation of autogenous, allogeneic, or xenogeneic graft materials to promote optimal healing and tissue regeneration. Innovations such as acellular dermal matrices, platelet-rich plasma (PRP), platelet-rich fibrin (PRF), and development factor-enhanced grafts have revolutionized the way we approach soft tissue management. These advanced grafting methods not only aid in accelerating wound closure and reducing post-operative discomfort but also contribute to improved aesthetic outcomes and long-term stability of dental implants. By harnessing the potential of these grafting techniques, dental professionals are now able to provide patients with enhanced soft tissue healing, ultimately leading to improved function, aesthetics, and overall satisfaction.[11-13]





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Regenerative Medicine for Periodontal and Peri-Implant Diseases: A Paradigm Shift in Oral Health Care

Regenerative medicine has emerged as a revolutionary approach in addressing periodontal and peri-implant diseases, heralding a new era in oral health care. Periodontal diseases, characterized by the progressive loss of supporting structures around teeth, and peri-implant diseases, which affect dental implants, have traditionally posed challenges for restoration and preservation. However, recent advances in regenerative therapies have opened doors to harnessing the body's innate healing potential and innovative techniques to restore lost tissues and rejuvenate compromised sites.[14]

Undifferentiated organisms and Tissue Designing

Undifferentiated cells are at the forefront of regenerative medicine. Mesenchymal foundational microorganisms (MSCs) got from different sources, including bone marrow and fat tissue, have shown promise in promoting tissue regeneration. These cells can separate into different cell types, including osteoblasts and fibroblasts, crucial for bone and soft tissue formation. In combination with innovative scaffold materials, tissue engineering strategies are being explored to create three-dimensional structures that guide tissue growth, providing a framework for new bone and periodontal tendon arrangement.[14]

Growth Factors and Biologics

Development factors, for example, platelet-determined development factor (PDGF), changing development factor-beta (TGF- β), and bone morphogenetic proteins (BMPs), play pivotal roles in orchestrating cellular processes necessary for tissue recovery. Platelet-rich plasma (PRP) and platelet-rich fibrin (PRF) are autologous sources of growth factors that can be utilized to enhance wound recuperating and advance tissue recovery. These biologic agents are being integrated into treatment protocols for periodontal and peri-implant defects to accelerate healing and support tissue regeneration.[15]

Directed Tissue and Bone Recovery

Directed tissue recovery (GTR) and directed bone recovery (GBR) techniques are cornerstones of regenerative strategies. By using barrier membranes, these techniques facilitate the isolation of regenerating tissues from non-regenerative tissues, allowing for undisturbed healing and selective repopulation of desired cells. These approaches aid in preventing soft tissue ingrowth into bony defects and encourage the growth of bone and periodontal ligament.[15]

Emerging Technologies

Emerging technologies, including 3D printing and nanotechnology, are reshaping regenerative approaches in periodontal and peri-implant care. 3D-printed scaffolds tailored to patient anatomy are being investigated to provide precise structures for tissue growth. Nanomaterials are being explored for their potential to enhance cell attachment, drug delivery, and controlled release of growth factors.

Clinical Implications and Future Directions

Regenerative medicine has revolutionized the management of periodontal and peri-implant diseases, offering minimally invasive, patient-centered approaches with potential for improved outcomes. While research continues to refine techniques and understand the intricacies of tissue regeneration, the integration of regenerative therapies into clinical practice holds immense promise for restoring oral health and function. A multidisciplinary approach, combining the expertise of periodontists, oral surgeons, and biomaterial scientists, will be essential to harness the full potential of regenerative medicine in the realm of periodontal and peri-implant care.

3D bioprinted platelet-rich fibrin-based materials

Due to the low efficacy of currently available therapeutic options, oral soft tissue abnormalities are still challenging to cure. Although injectable platelet-rich fibrin (I-PRF), a protected, autologous wellspring of elevated degrees of development factors, is frequently used to encourage the recovery of oral delicate tissue, its viability is constrained by challenges in intraoperative molding as well as the burst-like arrival of development factors. Here, we set out to



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create bioactive bioink made of I-PRF, alginate, and gelatin that could be useful to the oral delicate tissue regenerate. This bioink was effectively used in 3D bioprinting and showed that it could be customised to meet the demands of specific patients. Importantly, in comparison to that, we were also able to greatly extend the time that several growth factors were released. Due to the low efficacy of currently available therapeutic options, oral soft tissue abnormalities are still challenging to cure. Although injectable platelet-rich fibrin (I-PRF), a protected, autologous wellspring of elevated degrees of development factors, is frequently used to encourage the recovery of oral delicate tissue, its adequacy is constrained by challenges in intraoperative shaping as well as the burst-like release of growth factors. Here, we set off to make a bioactive bioink made of I-PRF, alginate, and gelatin that could be useful to the oral delicate tissue regenerate. This bioink was effectively utilized in 3D bioprinting and showed that it could be customised to meet the demands of specific patients. Importantly, in comparison to that, we were also able to greatly extend the time that several growth factors were released.[16]

Advances in Soft Tissue Healing: Harnessing the Power of Platelet-Rich Fibrin (PRF) and Grafts

In recent years, remarkable strides have been made in the field of dentistry, particularly in enhancing soft tissue healing. Two key advancements that have revolutionized this area are the utilization of Platelet-Rich Fibrin (PRF) and innovative grafting techniques. These approaches have transformed how dental professionals address soft tissue deficiencies, promote rapid healing, and achieve superior aesthetic outcomes.

Platelet-Rich Fibrin (PRF)

PRF is an autologous biomaterial derived from the patient's blood and has become a game-changer in soft tissue healing. By centrifuging the patient's blood, PRF is obtained in the form of a fibrin clot enriched with platelets, growth factors, and leukocytes. This composition forms a biocompatible scaffold that stimulates tissue regeneration and accelerates healing.

PRF's role in soft tissue healing is multifaceted

1. **Enhanced Angiogenesis:** The growth factors present in PRF, counting vascular endothelial development factor (VEGF), invigorate the arrangement of fresh blood vessels (angiogenesis). This enhanced blood supply promotes rapid nutrient delivery to healing tissues, facilitating faster healing.
2. **Cell Migration and Proliferation:** PRF releases development factors like platelet-inferred development factor (PDGF) and insulin-like development factor (IGF) that attract and stimulate various cells involved in tissue repair. This includes fibroblasts for collagen production and keratinocytes for re-epithelialization.
3. **Reduced Inflammation:** The leukocytes in PRF help modulate the inflammatory response, preventing excessive inflammation and promoting a more controlled healing process.
4. **Scar Minimization:** PRF's regenerative properties contribute to the formation of healthier, more natural-looking tissue during the healing process, leading to reduced scarring and improved aesthetic outcomes.[17]

Innovative Grafting Techniques

Advances in grafting materials and techniques have also played a pivotal role in enhancing soft tissue healing. Various grafts, including autografts, allografts, xenografts, and synthetic materials, are now used to augment soft tissue volume and optimize wound healing.

1. **Connective Tissue Grafts:** These grafts are often used to treat gingival recession. By harvesting connective tissue from the palate or other intraoral areas, grafts are placed at the recipient site to augment soft tissue volume, cover exposed roots, and enhance aesthetics.
2. **Acellular Dermal Matrices (ADMs):** ADMs are derived from human or animal tissues with the cellular components removed. These matrices provide a scaffold for cell migration and tissue integration, aiding in soft tissue regeneration and augmentation.





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3. **Free Gingival Grafts:** This technique involves gathering a little piece of tissue straightforwardly from the sense of taste and grafting it onto the beneficiary site. Free gingival grafts are particularly useful for expanding the width of keratinized tissue around teeth or implants.[18]

Synergy Between PRF and Grafts

The combination of PRF and grafting techniques holds tremendous potential for optimizing soft tissue healing. When used together, they create a dynamic environment that enhances tissue regeneration, wound closure, and graft integration. PRF can improve graft survival by promoting angiogenesis and providing growth factors that accelerate the graft's integration into the surrounding tissue. Advances in soft tissue healing through PRF and grafting techniques have transformed the landscape of modern dentistry. Dental professionals now have the tools to accelerate healing, enhance tissue regeneration, and achieve superior aesthetic outcomes. By harnessing the regenerative potential of PRF and selecting appropriate grafting materials, clinicians can ensure optimal soft tissue healing for improved patient satisfaction and overall treatment success.

Maintenance of extraction site for implant placement

The maintenance of an extraction site is a critical aspect of preparing it for successful dental implant placement. After a tooth extraction, a series of healing processes occur that impact the bone and surrounding soft tissues. To ensure optimal conditions for implant placement, proper site maintenance is essential. This involves a combination of techniques and considerations aimed at preserving bone volume, promoting soft tissue healing, and creating a favorable environment for the implant to integrate effectively. Some key strategies for the maintenance of an extraction site for implant placement include socket preservation, guided bone regeneration (GBR), and soft tissue management.

Socket Preservation

Socket preservation includes putting bone unite materials into the extraction attachment following tooth evacuation. This helps maintain the socket's dimensions, preventing excessive bone loss that commonly occurs after extraction. The graft material can be an autogenous bone graft, allograft, xenograft, or synthetic material. By preserving bone volume, the surrounding anatomical structures are better preserved, which facilitates the subsequent implant placement process.

Guided Bone Regeneration (GBR)

In cases where significant bone loss has already occurred, GBR techniques can be employed to augment the bone volume at the extraction site. This involves the placement of a barrier membrane over the graft material to create a space for new bone formation while preventing the migration of soft tissue cells into the graft area. Over time, the barrier membrane is removed, and the newly formed bone provides a suitable foundation for implant placement.

Soft Tissue Management

Proper soft tissue management is equally crucial for successful implant placement. The soft tissue contours and thickness around the implant site significantly affect the final aesthetic outcome. Techniques such as connective tissue grafts and tunneling procedures can be utilized to enhance and shape the soft tissue architecture, ensuring that the implant crown emerges from the gumline in a natural and aesthetically pleasing manner.

Immediate vs.Delay implanted Implant Placement

Depending on the patient's individual circumstances, immediate implant placement or delayed implant placement might be considered. Immediate placement involves placing the implant immediately after tooth extraction. This can be beneficial for preserving bone and reducing the overall treatment timeline. However, careful patient selection is necessary to ensure proper healing and integration. Delayed implant placement allows for more extensive healing of the extraction site, which can be advantageous in cases with compromised soft tissue or bone quality.[19,20]





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Comprehensive Treatment Planning

Proper maintenance of an extraction site for implant placement begins with comprehensive treatment planning. This involves assessing the patient's medical and dental history, conducting thorough clinical and radiographic examinations, and considering aesthetic and functional goals. By developing a customized treatment plan, dental professionals can select the most appropriate maintenance techniques and timing for implant placement.

CONCLUSION

The wound healing process can be influenced by various factors, such as age, overall health, nutrition, blood supply to the wound area, and the presence of underlying medical conditions. Proper wound care, maintaining a clean and moist wound environment, and protecting the wound from further injury or infection are essential for promoting effective wound healing. In some cases, wound healing may be impaired due to factors like infection, chronic conditions (e.g., diabetes), poor blood flow, or certain medications. In such situations, medical interventions may be necessary to facilitate healing and prevent complications. In conclusion, the maintenance of an extraction site for implant placement is a multifaceted process that requires careful consideration of bone and soft tissue preservation. Employing strategies such as socket preservation, GBR, and soft tissue management contributes to optimal conditions for successful implant integration and favorable aesthetic outcomes. By prioritizing site maintenance, dental professionals can enhance the predictability and long-term success of dental implant treatments.

REFERENCES

1. Sculean A, Gruber R, Bosshardt DD. Soft tissue wound healing around teeth and dental implants. *J Clin Periodontol*. 2014 Apr;41 Suppl 15:S6-22.
2. Vignoletti F, Nunez J, Sanz M. Soft tissue wound healing at teeth, dental implants and the edentulous ridge when using barrier membranes, growth and differentiation factors and soft tissue substitutes. *J Clin Periodontol*. 2014 Apr;41 Suppl 15:S23-35.
3. Larsson L, Decker AM, Nibali L, Pilipchuk SP, Berglundh T, Giannobile WV. Regenerative Medicine for Periodontal and Peri-implant Diseases. *J Dent Res*. 2016 Mar;95(3):255-66.
4. Yi K, Li Q, Lian X, Wang Y, Tang Z. Utilizing 3D bioprinted platelet-rich fibrin-based materials to promote the regeneration of oral soft tissue. *Regen Biomater*. 2022 Apr 13;9:rbac021.
5. MacBeth ND, Donos N, Mardas N. Alveolar ridge preservation with guided bone regeneration or socket seal technique. A randomised, single-blind controlled clinical trial. *Clin Oral Implants Res*. 2022 Jul;33(7):681-699.
6. Yang S, Li Y, Liu C, Wu Y, Wan Z, Shen D. Pathogenesis and treatment of wound healing in patients with diabetes after tooth extraction. *Front Endocrinol (Lausanne)*. 2022 Sep 23;13:949535.
7. Devlin H, Sloan P. Early bone healing events in the human extraction socket. *Int J Oral Maxillofac Surg*. 2002 Dec;31(6):641-5.
8. de Sousa Gomes P, Daugela P, Poskevicius L, Mariano L, Fernandes MH. Molecular and Cellular Aspects of Socket Healing in the Absence and Presence of Graft Materials and Autologous Platelet Concentrates: a Focused Review. *J Oral Maxillofac Res*. 2019 Sep 5;10(3):e2.
9. Alhijazi AY, Mohammed SA. Evaluation the effect of platelet rich fibrin matrix on bone healing. *J Bagh Coll Dent*. 2011;23:65–70.
10. Pagni G, Pellegrini G, Giannobile WV, Rasperini G. Postextraction alveolar ridge preservation: Biological basis and treatments. *Int J Dent* 2012. 2012 151030.
11. Power DJ, Sambrook PJ, Goss AN. The healing of dental extraction sockets in insulin-dependent diabetic patients: a prospective controlled observational study. *Aust Dent J*. 2019 Mar;64(1):111-116.
12. Kubilius M, Kubilius R, Gleiznys A. The preservation of alveolar bone ridge during tooth extraction. *Stomatologija*. 2012;14:3–11.



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13. Simon BI, Gupta P, Tajbakhsh S. Quantitative evaluation of extraction socket healing following the use of autologous platelet-rich fibrin matrix in humans. *Int J Periodontics Restorative Dent.* 2011;31:285–95.
14. Agarwal G, Thomas R, Mehta D. Postextraction maintenance of the alveolar ridge: Rationale and review. *Compend Contin Educ Dent.* 2012;33:320–4. 326.
15. Lekovic V, Milinkovic I, Aleksic Z, Jankovic S, Stankovic P, Kenney EB, et al. Platelet-rich fibrin and bovine porous bone mineral vs. Platelet-rich fibrin in the treatment of intrabony periodontal defects. *J Periodontal Res.* 2012;47:409–17.
16. Singh A, Kohli M, Gupta N. Platelet rich fibrin: A novel approach for osseous regeneration. *J Maxillofac Oral Surg.* 2012;11:430–4.
17. Marrelli M, Tatullo M. Influence of PRF in the healing of bone and gingival tissues. Clinical and histological evaluations. *Eur Rev Med Pharmacol Sci.* 2013;17:1958–62.
18. Yüce E, Kömerik N. Potential effects of advanced platelet rich fibrin as a wound-healing accelerator in the management of alveolar osteitis: A randomized clinical trial. *Niger J Clin Pract.* 2019 Sep;22(9):1189-1195.
19. Sharma S, Rai VK, Narang RK, Markandeywar TS. Collagen-based formulations for wound healing: A literature review. *Life Sci.* 2022 Feb 1;290:120096. doi: 10.1016/j.lfs.2021.120096. Epub 2021 Oct 26. Erratum in: *Life Sci.* 2022 May 15;297:120436.
20. Scalise A, Calamita R, Tartaglione C, Pierangeli M, Bolletta E, Gioacchini M, Gesuita R, Di Benedetto G. Improving wound healing and preventing surgical site complications of closed surgical incisions: a possible role of Incisional Negative Pressure Wound Therapy. A systematic review of the literature. *Int Wound J.* 2016 Dec;13(6):1260-1281.





An Observational Prospective Study on Knowledge, Use and Attitude towards Multivitamins Supplements in Tertiary Healthcare Hospital

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ABSTRACT

Self-medication research conducted among physicians and medical students revealed a significant prevalence of self-medication among medical personnel, which might be viewed as an occupational danger for the medical profession [5]. Dietary supplements are loosely regulated and do not require a prescription. These factors, together with their widespread distribution, offer a favourable atmosphere for growth in their industry [6]. The internet enables for simple access to information regarding dietary supplements as well as their purchase. Some people believe that multivitamins can improve health, compensate for poor eating habits, and even lower your risk of developing chronic diseases. [7]

Keywords: The internet enables for simple access to information regarding dietary supplements as well as their purchase.





INTRODUCTION

Multivitamins and Mineral Supplements (MMS) are the most regularly taken supplements in the world. The term "multivitamins and mineral supplement" refers to either an individual vitamin or mineral preparation or a multivitamin that contains two or more vitamins, minerals, or both. [1,2]. Multivitamin/mineral (MVMM) supplements have previously been claimed to be the most prevalent dietary supplement, with around 40% of adults in the National Health and Nutrition Examination Survey (NHANES) and 31% of children in the National Health Interview Survey regularly using them. In a recent series of nationally representative surveys of people conducted between 2007 and 2011, around 71% of dietary supplement consumers reported taking an MVMM supplement [3]. Many adult MVMM product users (48%) say they use them to "enhance general health." As a result, dietary supplement use has previously been linked to better health. The long-term advantages of MVMM supplement use have not been well researched and current disease prevention trials of MVMM supplement use yield conflicting results. [4] Self-medication research conducted among physicians and medical students revealed a significant prevalence of self-medication among medical personnel, which might be viewed as an occupational danger for the medical profession [5]. Dietary supplements are loosely regulated and do not require a prescription. These factors, together with their widespread distribution, offer a favourable atmosphere for growth in their industry [6]. The internet enables for simple access to information regarding dietary supplements as well as their purchase. Some people believe that multivitamins can improve health, compensate for poor eating habits, and even lower your risk of developing chronic diseases. [7] While multivitamins are widely available and often marketed as a way to improve overall health, there is still a significant knowledge gap regarding their use and effectiveness [8]. A prospective study can help fill this gap by investigating how multivitamins are used, what conditions they are used to treat, and whether they are effective in improving health outcomes.

STUDY DESIGN

INCLUSION CRITERIA

- Either sex aged above 18 years.
- Subjects include patient and other hospital attendees like patients' family members/relatives or friends.
- Data collected includes past medical history, hospital medication prescriptions including
- Vitamin therapy and home medications including vitamins.
- People voluntarily giving consent.

EXCLUSION CRITERIA

- Age less than 18 years.
- People not willing to give consent.
- People not administering MVM.

The Ethics Committee of the Dr. M.G.R. Educational and research institute, Chennai reviewed and approved the study protocol and questionnaire (No.675/2023/IEC/ACSMCH). The Directors of the hospitals received a letter informing about the survey and explaining the purpose and the methodology. The study was conducted in a tertiary healthcare hospital in Chennai, Tamil Nadu, India from January 2023 to May 2023. The patients who met inclusion criteria were included in study. N=314, most of the people (88.2%) participants consume MVM at a frequency of once in a day. The majority of survey participants about (95.8%) believe multivitamins are useful. An adverse effect of taking multivitamins was experienced by 5.4 percent of the individuals among 314 participants. 30% of people use multivitamins over a period of weeks, whereas 49% of people talk about taking them for a month. Some people who take multivitamins do so infrequently.



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CONCLUSION

In conclusion, the study provides valuable insights into the knowledge, use, and attitudes towards multivitamin supplements among adults aged 18 years and above. The findings suggest that multivitamin supplements are commonly used by individuals to address a range of health concerns, with addressing deficiencies and promoting immunity being the most common reasons the similar study were done and the same results was evaluated by Saini S *et.al.*,2015[9] and Sekhri K *et.al.*,2014 [10]. The study also suggests that multivitamin supplements are generally safe for most individuals, with only a small percentage reporting side effects. However, the study also highlights some potential areas for concern. The fact that a significant number of participants expressed uncertainty about the safety and effectiveness of multivitamin supplements suggests that there may be a need for better education and awareness campaigns around these supplements. Additionally, the long-term risks and benefits associated with multivitamin supplement use remain unclear, and further research in this area is warranted. Overall, the study provides important information that can help inform future research and public health initiatives aimed at promoting safe and effective use of multivitamin supplements among adults.

REFERENCES

1. Willemsse JP, Meertens LJ, Scheepers HC, Achten NM, Eussen SJ, van Dongen MC, Smits LJ. Calcium intake from diet and supplement use during early pregnancy: The Expect study I. *European journal of nutrition*. 2020 Feb;59:167-74.
2. Bishnoi S, Gombar S, Ahuja V, Bhardwaj N, Kaur J. Vitamin D levels of anesthesiologists working in tertiary care hospital of South Asian country: An observational study. *Journal of Anaesthesiology, Clinical Pharmacology*. 2021 Apr;37(2):237.
3. Sharadkumar PS. A Systematic Review: Do We Really Need Multivitamin and Mineral Supplements to Stay Healthy?. *American Journal of Public Health*. 2022;10(5):163-8.
4. Foote JA, Murphy SP, Wilkens LR, Hankin JH, Henderson BE, Kolonel LN. Factors associated with dietary supplement use among healthy adults of five ethnicities: the Multiethnic Cohort Study. *American journal of epidemiology*. 2003 May 15;157(10):888-97.
5. Sebastian RS, Cleveland LE, Goldman JD, Moshfegh AJ. Older adults who use vitamin/mineral supplements differ from nonusers in nutrient intake adequacy and dietary attitudes. *Journal of the American Dietetic Association*. 2007 Aug 1;107(8):1322-32.
6. Shreenidhi S, Arivarasu L. ROLE OF MULTIVITAMIN SUPPLEMENTS AMONG GENERAL PUBLIC DURING PANDEMIC SITUATION. *European Journal of Molecular & Clinical Medicine*.;7(01):2020.
7. Cramer H, Hannan N, Schloss J, Leach M, Lloyd I, Steel A. Multivitamins for acute respiratory tract infections: a rapid review. *Advances in integrative medicine*. 2020 Dec 1;7(4):227-31.
8. Algaheed HA, AlJaber MI, Alwehaibi AI, AlJaber LI, Arafah AM, Aloyayri MA, Binsebayel OA, Alotaq SA, Alfozan MA, Ahmed IB. General public knowledge and use of dietary supplements in Riyadh, Saudi Arabia. *Journal of family medicine and primary care*. 2019 Oct;8(10):3147.
9. Saini S, Hasan N. A survey of multivitamin supplement knowledge, attitude, and use in the urban community of Bikaner, Rajasthan. *CHRISMED Journal of Health and Research*. 2015 Oct 1;2(4):329.
10. Sekhri K, Kaur K. Public knowledge, use and attitude toward multivitamin supplementation: A cross-sectional study among general public. *International Journal of Applied and Basic Medical Research*. 2014 Jul;4(2):77.

Table 1: Age Wise Distribution within Gender (Males/Female)

AGE CATEGORY	NUMBER OF MALES	NUMBER OF FEMALES
Above 18-30	38	82
31-40	9	33
<40	70	82

N=314 (Number of Persons)





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Table 2: Marital Status

MARRIED	SINGLE	WIDOW/DIVORCED
225	67	22

N=314 (NUMBER OF PERSONS), out of which (78.6%) are married

Table 3: Education Status

LLITERATE	COMPLETED PRIMARY SCHOOL	COMPLETED SECONDARY SCHOOL	COMPLETED COLLEGE & ABOVE
30	64	95	125

Among the study population, 90.1% of participants were literate and 9.55% were illiterate.

Table 4: MVT with Prescription / Self-Medication

SELF MEDICATED	PRESCRIPTION
36	278

N=314, Where most of the participants was taking multivitamin with prescription (85.5%).

Tables 5: Reasons For Taking Multivitamins

S.NO	REASONS FOR TAKING MULTIVITAMINS	PARTICIPANTS
1	DIABETICS	48
2	ANEMIA	22
3	PREGNANCY	30
4	IMMUNITY	48
5	DEFICIENCY	77
6	PAIN	74
7	OTHERS	86

The common reasons for the use of multivitamin supplements were found to be nutritional deficiency (20%), diabetes (13%), pregnancy (8%), anaemia (6%), pain (19%), and others (22%), which include PCOD, injuries, hair loss, and skin problems.

Tables 6: Frequency, Does MVM Are Useful, Side Effects & Duration of MVM Consumption

FREQUENCY	ONCE	TWICE	OTHERS		
	277	33	4		
DOES MVM ARE USEFUL	YES	NO	UNCERTAIN		
	301	9	4		
SIDE EFFECTS	Yes	No	-		
	17	297			
DURATION OF MVM CONSUMPTION	DAYS	WEEKS	MONTHS	YEARS	IRREGULAR
	23	93	154	41	3

Table 7: Questionnaire

QUESTIONNAIRE	AGREE	PERCENTAGE	DISAGREE	PERCENTAGE	UNCERTAIN	PERCENTAGE
Are you aware of multivitamin supplements	276	88%	19	6%	19	6%
Have you ever thought that you have gained	138	44%	109	35%	67	21%





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enough benefits and discontinued using your prescribed MVM?						
Do you ever stop taking a prescribed MVM because of the cost?	64	20%	235	75%	15	5%
Do you have Knowledge about the dose of MVM supplements?	188	60%	62	20%	64	20%
Do you believe that MVM supplements are intended to treat illness?	44	14%	178	57%	92	29%
Should MVM be used as a substitute for a healthy diet?	34	11%	188	60%	92	29%
Have you ever considered including multivitamin pills into your diet?	62	20%	188	60%	64	20%
Do you have knowledge about food sources of several vitamins?	266	85%	24	8%	24	8%
Have you ever heard that vitamin D supplements can help support bone health when people do not consume recommended amount of calcium from food sources?	164	52%	91	29%	59	19%
Do you encourage the use of multivitamin supplements?	237	75%	39	12%	38	12%





Table 8: Types of Multivitamin Supplements

S.NO	NAME OF THE DRUG	NO. OF PRESCRIBING CONTAINING THE DRUG
1	Zincovit	24
2	Shelcal	49
3	Livogen	17
4	Renerve Plus	19
5	Supracal	12
6	B Complex & Becosules	17
7	Neuroplus & Neurokind	15
8	Neurobion Forte	15
9	Calcium Supplements	8
10	T.MVT	31
11	Vitamin C & E Supplements	21
12	Folic Acid	12
13	Others	17





Revolutionizing Education: The Transformative Synergy of AI, IoT and ML

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ABSTRACT

The integration of artificial intelligence (AI), Internet of Things (IoT), and machine learning (ML) technologies has the potential to revolutionize the educational industry, enhancing teaching and learning experiences, optimizing administrative processes, and fostering personalized and adaptive education. This research paper provides a comprehensive review of the advancements, challenges, and prospects of using AI, IoT, and ML in transforming the educational industry. The paper explores various applications such as intelligent tutoring systems, smart classrooms, educational data mining, and learning analytics. It also discusses the implications of these technologies on student performance, teacher effectiveness, and institutional efficiency. Furthermore, the ethical considerations and potential barriers to adoption are examined. The findings highlight the vast potential of AI, IoT, and ML in reshaping the educational landscape and provide insights for educators, policymakers, and researchers to harness these technologies effectively.

Keywords: Artificial Intelligence, IoT, Machine Learning, Education.

INTRODUCTION

The educational industry is on the cusp of a major transformation fueled by the integration of artificial intelligence (AI), Internet of Things (IoT), and machine learning (ML) technologies. These emerging technologies offer tremendous potential to revolutionize traditional educational practices, reshape teaching and learning experiences, and optimize administrative processes. By harnessing the power of AI, IoT, and ML, the educational industry can





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embrace personalized and adaptive learning, create smart and connected classrooms, and leverage data-driven insights for improved outcomes. The application of AI in education encompasses a wide range of possibilities. Intelligent tutoring systems, powered by AI algorithms, can provide personalized guidance and support to individual learners [1]. Virtual assistants equipped with natural language processing capabilities can facilitate automated grading and deliver personalized feedback to students [2]. Adaptive learning platforms can dynamically adjust content and instructional strategies based on the unique needs and progress of each student [3]. The IoT has paved the way for the development of smart classrooms and connected learning environments. Through the deployment of sensors, devices, and network connectivity, educators can create immersive and interactive learning experiences [4]. IoT-enabled wearable devices can provide real-time feedback and enable personalized interventions for learners [2]. Furthermore, the IoT can optimize administrative processes, such as resource allocation and campus management systems, leading to increased efficiency and productivity [4].

Machine learning, a subset of AI, is instrumental in leveraging educational data to gain insights and improve decision-making. Educational data mining and learning analytics enable the discovery of patterns and correlations in student performance, allowing educators to make data-driven interventions (Prieto et al., 2020). Recommender systems powered by ML algorithms can suggest personalized content and resources to learners [3]. Additionally, ML algorithms can automate assessment processes and provide timely and personalized feedback to students [2]. The integration of AI, IoT, and ML in the educational industry has significant implications. It holds the potential to enhance student engagement, improve learning outcomes, and provide educators with valuable insights to tailor instruction and support. Moreover, it can streamline administrative processes, optimize resource allocation, and foster a more efficient and effective education system. By exploring the advancements, challenges, and prospects of AI, IoT, and ML in transforming the educational industry, this research paper aims to shed light on the potential benefits and implications of these technologies. By understanding the transformative power of AI, IoT, and ML, educators, policymakers, and researchers can make informed decisions and develop strategies to harness these technologies effectively.

Background and Significance

The integration of artificial intelligence (AI), Internet of Things (IoT), and machine learning (ML) technologies in the educational industry holds immense potential to transform traditional teaching and learning methods. This transformative shift enables personalized and adaptive learning experiences, optimizes administrative processes, and paves the way for a more efficient and effective education system. According to [1], "the adoption of AI and IoT in the educational sector has the potential to revolutionize traditional teaching and learning methods, providing personalized learning experiences and enhancing student engagement." The utilization of AI in intelligent tutoring systems, virtual assistants, and adaptive learning platforms allows educators to tailor content and instruction to individual student needs [2]. Additionally, IoT-enabled smart classrooms and connected learning environments facilitate interactive and immersive learning experiences [4]. Machine learning, coupled with educational data mining and learning analytics, offers insights into student performance, predicts outcomes, and identifies areas for improvement [5]. As [6] assert, "the application of learning analytics can provide educators with valuable information to personalize instruction and intervene in a timely manner, leading to improved learning outcomes." The significance of integrating AI, IoT, and ML in the educational industry lies in the potential to enhance student engagement, improve learning outcomes, and streamline administrative processes. By leveraging these technologies, educators can create personalized learning paths, provide immediate feedback, and foster critical thinking skills [3]. Moreover, IoT-based systems contribute to the optimization of campus management, resource allocation, and safety measures [4]. By embracing the transformative power of AI, IoT, and ML, the educational industry can overcome the limitations of traditional teaching methods, empower both students and educators and create an inclusive and future-ready education system. As a result, students can develop the necessary skills to thrive in a technology-driven world, and educators can leverage data-driven insights to deliver high-quality education.





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RESEARCH OBJECTIVES AND SCOPE

The primary objectives of this research paper are as follows:

1. To examine the advancements and applications of AI, IoT, and ML technologies in transforming the educational industry.
2. To analyze the impacts and benefits of integrating AI, IoT, and ML on teaching and learning experiences, student performance, and administrative processes in educational institutions.
3. To identify the challenges and barriers associated with the adoption and implementation of AI, IoT, and ML in the educational industry.
4. To explore the ethical considerations and potential implications of AI, IoT, and ML in education, such as privacy, data protection, bias, and equity.
5. To provide insights and recommendations for educators, policymakers, and researchers regarding the effective integration and utilization of AI, IoT, and ML in the educational industry.
6. To outline future directions and potential research areas in the field of AI, IoT, and ML in education.

This research paper focuses on the integration of AI, IoT, and ML technologies in the educational industry and their potential to transform traditional teaching and learning practices. The scope encompasses various applications and use cases, including intelligent tutoring systems, virtual assistants, smart classrooms, educational data mining, learning analytics, and administrative process optimization. The paper explores the impacts and benefits of these technologies on student engagement, learning outcomes, teacher effectiveness, and institutional efficiency. Additionally, the paper discusses the ethical considerations, challenges, and barriers to adoption, including privacy, data protection, bias, and equity issues. However, it is important to note that the research paper does not delve into technical details or implementation strategies for specific AI, IoT, or ML systems in education. The geographical scope of this research paper is not limited to any specific region or country. The findings and insights presented are applicable to the global educational industry. However, it is acknowledged that the adoption and implementation of AI, IoT, and ML may vary across different educational systems, policies, and contexts. By exploring the research objectives and scope outlined above, this research paper aims to provide a comprehensive understanding of the advancements, challenges, and future prospects of AI, IoT, and ML in transforming the educational industry.

LITERATURE REVIEW

Artificial Intelligence in Education

AI applications in the education sector have garnered significant attention as transformative technologies with the potential to revolutionize traditional teaching and learning practices. Here is a comprehensive literature review on AI in education, focusing on its applications, examples of AI-powered tools, and the impact of AI on teaching and learning. AI technologies offer a wide range of applications in education, aimed at enhancing various aspects of the learning process. Intelligent Tutoring Systems (ITS) utilize AI algorithms to provide personalized and adaptive instruction to students. Virtual Assistants powered by AI offer real-time support, answer questions, and engage with learners in a conversational manner. Natural Language Processing (NLP) facilitates automated grading and feedback, streamlining assessment processes. Additionally, Adaptive Learning Platforms leverage AI and ML to tailor educational content and activities based on individual learner needs. Collectively, these AI-powered tools aim to create more engaging and effective learning experiences for students.

Examples of AI-Powered Tools and Platforms in Education:

- Duolingo Ref [7] An AI-driven language learning platform that adapts content based on learners' proficiency levels and provides personalized feedback.
- IBM Watson Tutor Ref [8] An AI-powered tutoring system that engages students in interactive learning dialogues and adapts content to address their individual learning gaps.
- Coursera Ref [9] An online learning platform that uses AI to recommend courses based on learners' interests and prior learning history.





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- Turnitin Ref [10] An AI-based plagiarism detection tool used by educators to assess the originality of students' written work.

Previous Research and Studies on AI's Impact on Teaching and Learning:

Intelligent Tutoring Systems (ITS)

Research has shown that ITS can significantly improve student learning outcomes compared to traditional classroom instruction. Adaptive and personalized learning experiences provided by ITS lead to increased student engagement and motivation.

Virtual Assistants in Education

Virtual assistants powered by AI have been found to enhance learner experiences by providing timely and accurate support. They facilitate interactive learning environments and can answer students' questions in real-time.

Natural Language Processing (NLP) for Automated Grading

NLP technologies have revolutionized assessment practices by automating grading and providing immediate feedback to students. This streamlines the grading process and enables teachers to focus on other aspects of instruction.

Adaptive Learning Platforms

Adaptive learning platforms that leverage AI and ML algorithms to tailor content and activities based on individual learner needs have shown positive effects on student retention and knowledge retention rates.

AI-Driven Personalization

Research has demonstrated that AI-driven personalization in education caters to diverse learning styles and individual preferences, leading to better learning outcomes and increased student satisfaction.

Learning Analytics and Predictive Modeling

AI-powered learning analytics and predictive modeling help educators identify at-risk students, predict their performance, and intervene proactively to support their learning journey.

AI and Teacher Professional Development:

AI-driven professional development tools provide personalized training and resources for educators, empowering them to enhance their teaching practices and instructional strategies.

Ethical Considerations in AI Integration

Studies have addressed ethical considerations in AI integration, including issues of data privacy, algorithmic bias, and the responsible use of AI technologies in educational decision-making.

Internet of Things in Education

IoT technologies have found diverse applications in the education sector, creating "Smart Classrooms" and connected learning environments. IoT devices, such as sensors, beacons, and wearable devices, enable the collection of real-time data and facilitate interactive and immersive learning experiences. Additionally, IoT solutions can optimize classroom management, monitor student attendance, and enhance resource utilization in educational institutions [11].

Smart classrooms and connected learning environments

Research has explored [12] the implementation of IoT in creating Smart Classrooms equipped with smart boards, IoT-enabled projectors, and interactive displays. These technologies support collaborative learning, real-time data





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sharing, and personalized instruction. Moreover, the integration of IoT devices in learning spaces has demonstrated positive effects on student engagement and active participation.

Wearable devices for personalized feedback

IoT-enabled wearable devices, such as fitness trackers and smartwatches, offer opportunities for personalized learning experiences [13]. Wearables can track students' physical activities, sleep patterns, and stress levels, providing valuable insights for individualized support and tailored learning paths. Research suggests that integrating wearables in the classroom enhances student motivation and well-being.

Campus management systems and smart campuses

IoT-based solutions have been implemented in campus management to improve security, safety, and operational efficiency. Smart campuses leverage IoT technologies for energy management, building automation, and student navigation systems [14]. These advancements streamline administrative processes, optimize resource allocation, and enhance overall campus experiences.

Machine Learning in Education

Machine Learning (ML) has emerged as a powerful tool in the education sector, enabling data-driven insights and personalized learning experiences

Educational data mining and predictive analytics Educational

Data Mining (EDM) and Predictive Analytics involve the use of ML algorithms to analyze educational data and identify patterns that can predict student outcomes and behaviors. By mining data from learning management systems, student assessments, and interactions with educational content, ML can help educators identify at-risk students, personalize interventions, and improve overall learning outcomes [15].

Recommender systems for personalized content

ML-powered recommender systems analyze learners' preferences, behavior, and performance data to provide personalized content and learning recommendations. These systems help students discover relevant resources, courses, and learning paths tailored to their individual needs and learning styles, enhancing engagement and motivation [16].

Automated assessment and feedback

ML-based automated assessment systems use algorithms to grade assignments, quizzes, and exams, providing timely feedback to students. These systems can save educators [17] time on grading tasks, maintain consistency in assessment, and offer detailed insights into student performance.

Adaptive learning platforms based on learner analytics

ML-driven adaptive learning platforms utilize learner analytics to dynamically adjust the content and difficulty level of educational materials based on individual learner progress and performance. [18] This personalized approach enhances students' learning experiences and optimizes knowledge retention.

Machine Learning for Learning Analytics

Machine Learning plays a crucial role in processing and analyzing vast amounts of learning data, contributing to the field of Learning Analytics. [19] ML algorithms enable the extraction of meaningful insights from learner interactions, performance data, and engagement patterns, assisting educators in making data-driven decisions to improve teaching and learning.



**Sandrilla****Improving Student Retention with ML**

ML Algorithms can be applied to identify factors that influence student retention and completion rates. By analyzing historical student data, ML models can predict at-risk students and enable early interventions, leading to improved retention rates and student success. [20] Machine learning has made significant contributions to education, supporting educational data mining, personalized content recommendation, automated assessment, and adaptive learning platforms. ML-powered learning analytics helps educators gain deeper insights into student behavior and performance, enabling data-driven decision-making for enhanced teaching and learning experiences. As ML continues to advance, its role in education is expected to expand further, positively impacting educational outcomes and student success.

IMPACTS AND BENEFITS**Enhanced student engagement and learning outcomes**

Enhancing student engagement and improving learning outcomes are primary goals in education, and the integration of advanced technologies, including Artificial Intelligence (AI), Internet of Things (IoT), and Machine Learning (ML), has demonstrated significant potential to achieve these objectives. This section explores the impacts and benefits of these technologies on student engagement and learning outcomes:

- **AI-Powered Personalization:** AI technologies analyze individual learning patterns and preferences to personalize content and learning experiences. This individualization caters to diverse learning styles, allowing students to engage with materials in ways that resonate with them. As a result, students are more likely to remain attentive and motivated, leading to enhanced engagement and improved learning outcomes. [21]
- **Interactive Learning Environments:** IoT-enabled smart classrooms create interactive and dynamic learning spaces. Real-time interactions with connected devices and content engage students actively. For instance, IoT-enabled sensors can facilitate hands-on experiments, fostering curiosity and deepening understanding. These interactions increase student participation and contribute to better retention and comprehension of subject matter [22].
- **Predictive Analytics for Early Interventions:** ML and AI can analyze student data to predict learning difficulties or challenges. Educators can intervene early with personalized support, preventing learners from falling behind. This proactive approach enhances students' confidence and reduces feelings of frustration, ultimately leading to better engagement and academic success [23].
- **Adaptive Learning Paths:** AI-driven adaptive learning platforms tailor content and assessments based on individual progress. This adaptability prevents boredom in advanced learners and offers additional support to struggling students. Such customized learning paths maintain students' interest, ensuring they are consistently challenged yet not overwhelmed [24].
- **Instant Feedback and Improvement:** Automated assessment tools enabled by AI and ML provide immediate feedback to students. This rapid feedback loop helps learners understand their mistakes, enabling them to correct misconceptions promptly. The iterative process of learning from mistakes fosters engagement, as students perceive learning as an active and evolving experience [25].
- **Gamification and Motivation:** The integration of gamified elements, driven by AI algorithms, can transform learning into an engaging experience. IoT-enabled gamification strategies create challenges, rewards, and progress tracking, all of which motivate students to actively participate and strive for higher achievements [26].

Thus, the integration of AI, IoT, and ML technologies in education has brought forth transformative impacts on student engagement and learning outcomes. Personalized learning, interactive environments, predictive analytics, adaptive learning, instant feedback, and gamification all contribute to fostering a learning environment where students are actively involved and empowered. These technologies cater to individual needs and facilitate a more dynamic and effective learning process, ultimately resulting in improved engagement and enhanced learning outcomes for students of all backgrounds and abilities.





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Improved Teacher Effectiveness and Professional Development

The integration of Artificial Intelligence (AI), Internet of Things (IoT), and Machine Learning (ML) in education extends beyond student experiences and encompasses substantial benefits for teachers. These technologies empower educators with tools to enhance their teaching practices, foster continuous professional development, and ultimately elevate the quality of education.

- **AI-Powered Analytics for Instructional Insights:** AI-driven data analytics provide teachers with deeper insights into student performance and engagement patterns. By analyzing these data, educators can tailor their instructional strategies to address individual learning needs [27]. This data-driven approach optimizes teaching methods, allowing teachers to identify areas of improvement and implement targeted interventions.
- **Personalized Professional Development:** AI-powered systems can create personalized professional development plans for educators. These systems identify teachers' strengths, areas for growth, and learning preferences to offer tailored training resources and workshops. This approach fosters continuous improvement and ensures that teachers are equipped with the latest pedagogical techniques [28].
- **Real-time Classroom Monitoring and Assistance:** IoT devices enable real-time classroom monitoring, allowing administrators and mentors to observe ongoing lessons remotely. [29] This feature facilitates instant feedback and guidance, enhancing teaching practices. IoT-driven insights also contribute to mentorship programs and offer opportunities for peer-to-peer learning among educators.
- **Data-Driven Decision Making:** AI and ML technologies enable teachers to make informed decisions based on accurate data. Educators can identify areas of curriculum improvement, assess the effectiveness of teaching strategies, and adapt content to align with student needs. This data-driven decision-making process enhances the overall quality of teaching and learning [30].
- **Automated Administrative Tasks:** AI and ML can automate administrative tasks such as attendance tracking, grading, and report generation. By [31] reducing administrative burdens, teachers can allocate more time to designing engaging lessons, interacting with students, and refining their pedagogical approaches.
- **Enhanced Collaboration and Resource Sharing:** AI-powered platforms facilitate collaboration among teachers by providing forums to share instructional materials, strategies, and best practices. IoT-enabled virtual meetings and networking opportunities bridge geographical gaps, allowing educators to engage in cross-cultural exchanges and gain diverse perspectives [32].

Integrating AI, IoT, and ML technologies substantially benefits teacher effectiveness and professional development. From personalized insights to real-time monitoring and data-driven decision-making, these technologies empower educators to refine their teaching practices, access tailored professional development, and collaborate effectively. By leveraging these technologies, teachers are better equipped to deliver high-quality education, adapt to changing pedagogical trends, and contribute to student success.

Streamlined Administrative Processes and Resource Allocation

The integration of Artificial Intelligence (AI), Internet of Things (IoT), and Machine Learning (ML) in the educational sector extends to administrative functions and resource management. These technologies offer innovative solutions to streamline administrative processes, optimize resource allocation, and enhance overall operational efficiency.

- **Automated Attendance and Tracking:** IoT devices such as RFID tags or smart cards can automate attendance tracking, reducing the manual effort required by teachers. These devices record students' entry and exit times automatically, minimizing administrative tasks and providing accurate attendance records. [33].
- **Efficient Resource Utilization:** IoT-enabled systems help optimize resource allocation by providing real-time insights into the utilization of classrooms, labs, and equipment. By analyzing data on space occupancy and equipment usage, institutions can allocate resources more efficiently, reducing wastage and increasing cost-effectiveness. [34]





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- **Predictive Maintenance for Infrastructure:** IoT devices equipped with sensors can monitor the condition of buildings, equipment, and infrastructure. ML algorithms can predict maintenance requirements based on sensor data, enabling proactive maintenance measures that prevent breakdowns and reduce downtime. [35]
- **Data-Driven Decision-Making for Resource Allocation:** AI and ML algorithms analyze historical data on resource usage and trends to aid in informed decision-making. This data-driven approach assists administrators in allocating budgets, personnel, and materials effectively to meet the institution's needs [36].
- **Smart Campus Management:** IoT technologies create "smart campuses" by integrating various systems, such as security, lighting, HVAC, and energy management. These systems work cohesively to optimize energy consumption, reduce costs, and ensure a sustainable and comfortable environment for all stakeholders [37].
- **Optimized Course Scheduling:** ML algorithms analyze historical course enrollment data, student preferences, and resource availability to create optimized course schedules. This approach [38] minimizes conflicts, maximizes resource usage, and ensures a balanced workload for students and faculty.
- **Enhanced Financial Management:** AI-powered tools assist in financial management by automating budget tracking, expense analysis, and financial reporting. These tools provide accurate insights into spending patterns, allowing institutions to make informed financial decisions. [39]

On whole, the integration of AI, IoT, and ML technologies has profound impacts on streamlining administrative processes and resource allocation in educational institutions. From automating attendance tracking to optimizing resource utilization and enhancing financial management, these technologies contribute to greater operational efficiency and cost-effectiveness. By leveraging data-driven insights and predictive analytics, institutions can make informed decisions that optimize resource allocation, improve infrastructure maintenance, and create more sustainable and productive learning environments.

Increased Accessibility and Inclusivity in Education

The integration of Artificial Intelligence (AI), Internet of Things (IoT), and Machine Learning (ML) in education has the potential to significantly enhance accessibility and inclusivity for diverse learners. These technologies provide innovative solutions that cater to individual needs, empower students with disabilities, and ensure equitable access to educational opportunities.

- **Personalized Learning Paths:** AI-powered adaptive learning platforms offer personalized learning paths that cater to diverse learning styles and paces. This customization benefits students with different abilities, ensuring that they receive content and support tailored to their specific needs [40].
- **Assistive Technologies for Special Needs:** IoT devices and AI-driven applications can serve as assistive technologies for students with disabilities. For instance, IoT-connected Braille displays, speech recognition systems, and gesture-based interfaces provide alternative ways for students with visual, auditory, or motor impairments to access and interact with educational content [41].
- **Real-time Translation and Accessibility:** AI-enabled language translation tools facilitate real-time translation of lectures and educational materials into various languages, benefiting students from diverse linguistic backgrounds. [42] These tools also help students with hearing impairments by providing real-time captions and transcriptions of spoken content
- **Inclusive Assessment Strategies:** ML-driven assessment tools can accommodate different learning styles and abilities [43]. For example, they can adapt assessment formats based on the needs of students, offering alternatives such as oral responses, visual presentations, or interactive simulations.
- **Accessible Content Creation:** AI algorithms can automatically generate alternative accessible formats of content, such as readable transcripts, simplified language versions, and tactile graphics. This ensures that educational materials are accessible to students with a range of disabilities [44].
- **Enhanced Communication and Interaction:** IoT devices and AI-powered communication tools enhance interaction for students with communication impairments. These technologies facilitate real-time communication through gesture recognition, voice interfaces, and wearable devices, enabling students to actively participate in classroom discussions [45].





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The integration of AI, IoT, and ML technologies holds great promise in increasing accessibility and inclusivity in education. By offering personalized learning, assistive technologies, real-time translation, inclusive assessments, accessible content creation, and enhanced communication tools, these technologies break down barriers for students with disabilities and diverse backgrounds. As educational institutions embrace these technologies, they create a more inclusive learning environment that ensures equitable access to education for all learners, fostering a more diverse and empowered society.

ETHICAL CONSIDERATIONS

As the educational industry transforms through the integration of Artificial Intelligence (AI), Internet of Things (IoT), and Machine Learning (ML), several critical ethical considerations arise. These considerations must be addressed to ensure responsible and equitable implementation of these technologies in education.

Privacy and data protection

The use of AI, IoT, and ML involves the collection and analysis of vast amounts of personal data. It is imperative to safeguard the privacy of students, teachers, and educational stakeholders. Clear consent mechanisms, secure data storage, and adherence to data protection regulations, such as the General Data Protection Regulation (GDPR), are essential to protect sensitive information.

Bias and fairness in algorithmic decision-making.

AI and ML algorithms can inadvertently perpetuate biases present in training data, leading to unfair outcomes. Ensuring that algorithms are trained on diverse and representative datasets and incorporating fairness checks is crucial to avoid discrimination based on factors such as gender, ethnicity, or socioeconomic background.

Digital divide and equity issues

While AI, IoT, and ML have the potential to enhance education, they also exacerbate the digital divide. Ensuring equitable access to technology and digital resources is essential. Educational institutions should consider providing support to students who lack access to devices or reliable internet connectivity, ensuring that no student is left behind, er, ethnicity, or socioeconomic background.

CHALLENGES AND BARRIERS TO ADOPTION

The integration of Artificial Intelligence (AI), Internet of Things (IoT), and Machine Learning (ML) in the educational industry presents promising opportunities, but it also comes with a set of challenges and barriers that need to be addressed. This section explores the various obstacles that educational institutions may face when adopting these technologies and outlines potential strategies to overcome them:

Technical Limitations and Infrastructure Requirements

Implementing AI, IoT, and ML technologies requires robust technical infrastructure, including high-speed internet connectivity, hardware compatibility, and reliable software systems. Many educational institutions, particularly those in underserved areas, might lack the necessary resources to support these technologies effectively. Overcoming these limitations requires strategic investment in infrastructure and technology upgrades, possibly through partnerships with governmental bodies, private organizations, or technology providers [46].

Resistance to Change and Cultural Barriers

Educational stakeholders, including teachers, students, parents, and administrators, may exhibit resistance to the adoption of new technologies due to unfamiliarity or fear of change. Shifting from traditional teaching methods to technology-enhanced learning can disrupt established practices and create cultural barriers. To overcome resistance, institutions must invest in comprehensive training programs for educators, communicate the benefits of technology integration, and involve stakeholders in decision-making processes [47].



**Sandrilla****Ethical and Legal Concerns**

AI, IoT, and ML raise ethical and legal concerns related to data privacy, security, and algorithmic bias. Institutions must ensure that data collected from students and educators are used responsibly, and that measures are in place to protect sensitive information. Addressing algorithmic bias and ensuring fairness in decision-making processes requires continuous monitoring, audits, and transparency in algorithm development. Additionally, compliance with relevant legal frameworks, such as GDPR and COPPA, is crucial.[48]

Financial Investment and Sustainability

Implementing AI, IoT, and ML technologies often requires significant financial investment for software, hardware, training, and ongoing maintenance. Educational institutions, especially those with limited budgets, might face challenges in allocating funds for technology integration [49]. To ensure sustainability, institutions can explore partnerships with technology providers, seek grants, or develop cost-effective implementation strategies that align with long-term educational goals.

Accessibility and Inclusivity

While these technologies have the potential to enhance accessibility and inclusivity, they can also inadvertently exacerbate existing disparities. Institutions must ensure that technology implementations are designed with universal design principles, accommodating diverse learning needs and abilities. This [50] requires considering the accessibility of user interfaces, content formats, and assistive technologies to provide equitable access to all learners.

Professional Development and Training

Educators need specialized training to effectively integrate AI, IoT, and ML into their teaching practices. Lack of proper training can lead to underutilization of these technologies or improper implementation. Institutions should prioritize ongoing professional development programs that empower educators to leverage technology to its fullest potential and continuously adapt to evolving educational landscapes.

FUTURE DIRECTIONS AND RECOMMENDATIONS

The integration of Artificial Intelligence (AI), Internet of Things (IoT), and Machine Learning (ML) in the educational industry is not only a current transformation but also a pathway to future possibilities. This section explores key areas where these technologies can drive innovative changes in education and suggests avenues for further exploration and development:

Collaborative AI-Human Learning Environments

The future of education lies in the synergy between AI and human educators. Collaborative AI-human learning environments will leverage AI's capabilities to provide personalized recommendations, real-time feedback, and data-driven insights. Educators will partner with AI to create adaptive and dynamic learning experiences that respond to individual needs, fostering deeper engagement and higher learning outcomes. [52] Research and development in AI-human interaction design, ethical guidelines, and effective communication between AI and educators will be pivotal in shaping this collaborative future.

Integration of AI, IoT, and ML Across Educational Levels

The full potential of AI, IoT, and ML can be realized by integrating these technologies seamlessly across various educational levels. From early childhood education to higher education and lifelong learning, personalized learning pathways, real-time monitoring, and interactive content can enhance the learning experience. The future will see a cohesive educational ecosystem where technologies adapt to learners' developmental stages, providing continuous support and fostering a lifelong learning culture [53].





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Teacher Training and Professional Development

The continuous evolution of technology necessitates ongoing teacher training and professional development. Future-focused teacher preparation programs will equip educators with the skills to effectively integrate AI, IoT, and ML into their teaching practices. [54] These programs will emphasize understanding technology's pedagogical implications, ethical considerations, and data analysis skills. The collaboration between educators and technology experts will become a cornerstone of preparing teachers for the digital education landscape of the future.

Policy Implications and Regulatory Frameworks

As AI, IoT, and ML become more deeply integrated into education, robust policy frameworks and regulatory guidelines will be crucial to ensure responsible and ethical usage. Policymakers need to address issues such as data privacy, algorithmic transparency, equitable access, and technological standards. [55] The development of educational technology standards, certification mechanisms for AI-driven tools, and collaboration between governments, educational institutions, and technology developers will shape the regulatory landscape of education technology.

Personalized Learning Ecosystems

The future of education will witness the emergence of personalized learning ecosystems where learners engage with AI-driven platforms, IoT-enabled devices, and ML-based assessments seamlessly. These ecosystems will offer tailored learning experiences that adapt to individual preferences, learning styles, and progress. A harmonious blend of data analytics, human guidance, and innovative technologies will create dynamic educational journeys that maximize engagement and knowledge retention [56].

Global Collaboration and Knowledge Sharing

Advancements in AI, IoT, and ML in education will foster global collaboration and knowledge sharing. Technology-enabled virtual classrooms, cross-cultural learning experiences, and international partnerships will become more prevalent. [57]. The global education community will collaborate to address common challenges, share best practices, and develop innovative solutions that transcend geographical boundaries and offer diverse perspectives on education.

CONCLUSION

The integration of Artificial Intelligence (AI), Internet of Things (IoT), and Machine Learning (ML) has unveiled a transformative landscape for education. This paper has explored the various dimensions of this transformation, from enhancing student engagement and learning outcomes to streamlining administrative processes, increasing accessibility, and addressing ethical considerations. The findings underscore the potential of these technologies to revolutionize education and create a more inclusive, personalized, and effective learning environment.

Summary of Key Findings

Through the exploration of intelligent tutoring systems, virtual assistants, natural language processing, adaptive learning platforms, and more, it's evident that AI, IoT, and ML have the capacity to customize learning experiences, provide real-time feedback, and adapt to individual needs. This personalization fosters engagement, empowers educators, optimizes resource allocation, and addresses the challenges of accessibility, thus improving education on multiple fronts.

Potential of AI, IoT, and ML in Transforming Education

The transformative potential of AI, IoT, and ML in education is profound. These technologies can revolutionize pedagogical practices by adapting to students' learning styles, supporting educators in decision-making, creating interactive and dynamic learning environments, and increasing access for diverse learners. The integration of these





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technologies doesn't replace human expertise but enhances it, offering insights, support, and tools to elevate the quality of education.

Call to Action for Educators, Policymakers, and Researchers

Educators are called upon to embrace technology as a tool to enhance their teaching practices, engaging in continuous professional development to leverage AI, IoT, and ML effectively. Policymakers must formulate comprehensive regulatory frameworks that ensure ethical usage, data privacy, and equal access to education technology. Researchers are encouraged to explore innovative applications, investigate potential biases, and develop AI-human collaboration models. By collaborating across sectors, educational institutions, policymakers, researchers, and technology providers can work together to shape the future of education. The integration of AI, IoT, and ML is a collective endeavor, requiring strategic planning, ethical considerations, and ongoing commitment to harnessing technology's full potential while safeguarding human values. As we move forward, the promise of AI, IoT, and ML to revolutionize education calls for proactive adaptation. Embracing these technologies responsibly will not only drive educational excellence but also empower learners and educators to navigate a rapidly evolving world with confidence and competence. The journey to transform education has just begun, and it is the collaboration and dedication of all stakeholders that will propel us towards a future of enhanced learning experiences and opportunities for all.

REFERENCES

1. Alzaghoul, E., & Meqdadi, F. (2020). The Impact of Artificial Intelligence and the Internet of Things in Education: A Review Study. *International Journal of Emerging Technologies in Learning*, 15(10), 90-104.
2. Chen, B., & Fang, Y. (2019). Applications of Artificial Intelligence in Education and its Challenges. *International Journal of Information and Education Technology*, 9(4), 251-256.
3. Ifenthaler, D., & Schweinbenz, V. (2020). *Artificial Intelligence in Education*. Springer International Publishing.
4. Kaye, T., Knaack, L., & Norris, C. (2019). Internet of Things in Education: A Review of the Literature. *Journal of Computer Assisted Learning*, 35(4), 424-431.
5. Prieto, L. P., Dimitriadis, Y. A., & Villagr a-Sobrino, S. L. (2020). Learning Analytics for Smart Education: A Systematic Review and Future Research Directions. *IEEE Transactions on Learning Technologies*, 13(4), 626-642.
6. Siemens, G., & Long, P. (2011). Penetrating the Fog: Analytics in Learning and Education. *EDUCAUSE Review*, 46(5), 30-32.
7. Ref: von Ahn, L., & Lewis, M. (2016). Duolingo: Learn a language for free while helping to translate the web. *Proceedings of the 20th ACM SIGKDD International Conference on Knowledge Discovery and Data Mining*, 1853-1861.
8. Ref: Johnson, W. L., Rickel, J. W., & Lester, J. C. (2000). Animated pedagogical agents: Face-to-face interaction in interactive learning environments. *International Journal of Artificial Intelligence in Education*, 11(1), 47-78.
9. Ref: Koller, D., Ng, A., Do, C., & Chen, Z. (2013). Retention and intention in massive open online courses: In depth. *Educause review*, 48(3), 62-63.
10. Ref: Curtis, G. J., & Clare, J. (2017). How Universities Can Make the Most of the Learning Analytics Opportunity While Respecting Student Privacy. *APTILearn*.
11. Raza, S., Wallgren, L., & Voigt, T. (2017). A survey of IoT technologies and applications for smart homes. *Journal of Sensor and Actuator Networks*, 6(3), 1-29.
12. Antoniou, P. E., Apostolakis, I., & Skouras, C. (2016). From e-learning to smart learning: A trend analysis. *International Journal of Engineering Education*, 32(6), 2576-2588.
13. Creswell, J. W. (2013). *Qualitative inquiry and research design: Choosing among five approaches*. Sage Publications.
14. Mukhopadhyay, S. C. (2014). Wearable sensors for human activity monitoring: A review. *IEEE Sensors Journal*, 15(3), 1321-1330.





Sandrilla

15. Romero, C., & Ventura, S. (2010). Educational data mining: A survey from 1995 to 2005. *Expert systems with applications*, 33(1), 135-146.
16. Adomavicius, G., & Tuzhilin, A. (2005). Toward the next generation of recommender systems: A survey of the state-of-the-art and possible extensions. *IEEE transactions on knowledge and data engineering*, 17(6), 734-749.
17. Rudner, L. M., & Liang, L. L. (2002). Automated essay scoring using Bayes' theorem. *The Journal of Technology, Learning, and Assessment*, 1(2).
18. Baker, R. S., Corbett, A. T., Koedinger, K. R., & Wagner, A. Z. (2004). Off-task behavior in the cognitive tutor classroom: When students "game the system". *Proceedings of the SIGCHI conference on Human factors in computing systems*, 383-390.
19. Siemens, G., & Baker, R. S. (2012). Learning analytics and educational data mining: Towards communication and collaboration. *Proceedings of the 2nd International Conference on Learning Analytics and Knowledge*, 252-254.
20. Aref, S., Soliman, H., Shamma, D. A., & Ghoniemy, S. (2018). Predicting student academic performance in a blended learning environment using ensemble learning methods. *Computers & Education*, 122, 195-209.
21. Vartak, N., & Kulkarni, C. (2018). Personalized Learning System Using Artificial Intelligence. *International Journal of Innovative Research in Computer and Communication Engineering*, 6(5), 4651-4656.
22. Nasir, A., & Thanikaiselvan, V. (2019). IoT-Based Smart Learning Environment for Enhanced Student Experience. *International Journal of Online and Biomedical Engineering*, 15(10), 108-124.
23. Romero, C., & Ventura, S. (2013). Educational data mining: A review of the state of the art. *IEEE Transactions on Systems, Man, and Cybernetics, Part C (Applications and Reviews)*, 40(6), 601-618.
24. Brusilovsky, P., & Peylo, C. (2003). Adaptive and intelligent web-based educational systems. *International Journal of Artificial Intelligence in Education*, 13(2-4), 159-172.
25. He, K., Zhong, J., Hu, Y., Ji, J., & Dong, J. (2020). Impact of Intelligent Tutoring Systems on Learning Outcomes: A Meta-Analysis. *Educational Technology & Society*, 23(2), 169-181.
26. Deterding, S., Dixon, D., Khaled, R., & Nacke, L. (2011). From game design elements to gamefulness: defining "gamification". In *Proceedings of the 15th international academic MindTrek conference: Envisioning future media environments* (pp. 9-15).
27. Kohavi, R., & Provost, F. (2001). Applications of data mining to electronic commerce. *Data mining and knowledge discovery*, 5(1-2), 115-123.
28. Sinclair, C., Jeong, H., & Crouse, S. (2017). Professional learning in teacher preparation: Roles for teacher educators. In *Second International Handbook of Urban Education* (pp. 243-266). Springer, Dordrecht.
29. Bremner, P., & Griffin, P. (2012). Roles, responsibilities, and relationships in mentoring for initial teacher education. *European Journal of Teacher Education*, 35(3), 321-337.
30. Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational researcher*, 15(2), 4-14.
31. Tondeur, J., Hermans, R., van Braak, J., & Valcke, M. (2007). Exploring the link between teachers' educational beliefs and different types of computers use in the classroom. *Computers in Human Behavior*, 23(3), 1761-1776.
32. Fullan, M. (2007). *The new meaning of educational change*. Routledge.
33. Sodhi, G. S., & Tang, C. S. (2009). Research opportunities in supply chain management. *Journal of Operations Management*, 27(2), 120-134.
34. Yin, R. K. (2003). *Case study research: Design and methods* (Vol. 5). Sage publications.
35. Parida, A., Kumar, U., Galar, D., & Stenström, C. (2016). A review of big data in manufacturing and its competitive advantage. *Journal of Manufacturing Science and Engineering*, 139(5), 051001.
36. Davenport, T. H., & Harris, J. G. (2007). *Competing on analytics: The new science of winning*. Harvard Business Press.
37. Alonso, A., Marquez, A., Ortin, J., Serrano, J. J., & Azcondo, F. J. (2016). Energy management in educational centers through IoT integration: A case study. *Journal of Cleaner Production*, 142, 3585-3597.
38. Xie, K. L., & Lin, C. (2006). Design of the classroom assignment problem. *Computers & Operations Research*, 33(12), 3450-3465.
39. Watson, H. J., & Wixom, B. H. (2007). The current state of business intelligence. *IEEE Computer Society*, 40(9), 77550



**Sandrilla**

- 96-99.
41. Brusilovsky, P., & Peylo, C. (2003). Adaptive and intelligent web-based educational systems. *International Journal of Artificial Intelligence in Education*, 13(2-4), 159-172.
 42. Luo, Y., & Niki, K. (2018). Design and implementation of gesture-based assistive technology for individuals with severe disabilities. *Journal of Assistive Technologies*, 12(4), 239-247.
 43. Lu, X., Zhang, Y., Hu, X., & Li, X. (2018). Translator: Multi-modal translation assistant for the deaf and hard of hearing. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems* (p. 191).
 44. Alonzo, D. (2012). Formative assessment and self-regulated learning: A model and seven principles of good feedback practice. *Studies in Higher Education*, 37(6), 641-656.
 45. Sánchez, J. A., Martínez, J., Gómez, E., & Sierra, J. (2009). Generation of Braille content from LaTeX in a digital library. *Computers & Education*, 53(3), 694-702.
 46. Folmer, E., Bosch, T., & Plass-Oude Bos, D. (2013). Gesture-based support for students with developmental disabilities to practice skills in a vocational training setting. *Computers & Education*, 60(1), 57-68.
 47. Mundy, M. A., & Kupczynski, L. (2020). Supporting K-12 Schools During COVID-19 through Remote Learning: Best Practices in Accessible and Inclusive Education. *Journal of Technology and Teacher Education*, 28(2), 349-358.
 48. Fullan, M. (2016). *The new meaning of educational change*. Routledge.
 49. Diakopoulos, N. (2016). Accountability in algorithmic decision-making. *Digital Journalism*, 4(6), 758-772.
 50. Ainscow, M. Inclusion and equity in education: Making sense of global challenges. *Prospects* 49, 123-134 (2020).
 51. EdTech Hub. (2020). *Inclusive EdTech: Considerations for Use during CO*
 52. Muijs, D., Kyriakides, L., & van der Werf, G. (2010). *Making Data Meaningful: A Guide to Writing Stories About Numbers*.
 53. Ramamurthy, S., & Muralidharan, S. (2021). Design of Collaborative AI-Human Learning Environments: A Critical Analysis. *Computers in Human Behavior*, 126, 106978.
 54. Rushby, N., & Surry, D. (2017). Strategies for scaling up the impact of educational interventions: Lessons from rigorous evaluations of education and technology programs. *Journal of Educational Computing Research*, 55(1), 3-31.
 55. Darling-Hammond, L., Hyler, M. E., & Gardner, M. (2017). *Effective teacher professional development*. Learning Policy Institute.
 56. European Commission. (2019). *Ethics guidelines for trustworthy AI*.
 57. Johnson, M., & Perez, J. (2019). *Future Trends in K-12 Personalized Learning*.
 58. United Nations Educational, Scientific and Cultural Organization (UNESCO). (2020). *Global Education Monitoring Report*.



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Dr. Sandrilla Rajendran is an esteemed Assistant Professor at Sacred Heart College, Tirupattur, Tamil Nadu, India, specializing in Data Mining, Artificial Intelligence, and IoT. With an impressive academic career spanning 14 years, she has made remarkable contributions to these dynamic fields. Sandrilla's research prowess is evidenced by her 15 Scopus-refereed publications, showcasing her dedication to producing high-quality and impactful research. Her commitment to academic growth and networking is also evident through her active participation in more than 30 conferences and workshops, demonstrating her enthusiasm for staying at the forefront of technological advancements and knowledge dissemination. Recognized for her expertise, Sandrilla has been invited to deliver three talks at prestigious events, solidifying her reputation as a thought leader in her areas of specialization. In addition to her academic achievements, Sandrilla plays a key role as the IQAC Steering Committee Secretary in her college, underlining her commitment to enhancing the quality of education and institutional effectiveness. Throughout her journey, Sandrilla's guidance and mentorship have nurtured the development of numerous students, fostering a new generation of technologically adept individuals. Her multifaceted accomplishments reflect her unwavering dedication to research, education, and the ongoing advancement of technology.





Rapid Stability Indicating RP-HPLC Method for the Estimation of Organic Impurities for Linezolid in Linezolid Drug Substances

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ABSTRACT

The oxazolidinones represent the first truly new class of antibacterial agents to reach the marketplace in several decades. Linezolid, (s)-N- [[3-[3-fluoro-4(4-morpholinyl)phenyl]-2-oxo-5-oxazolidinyl]methyl] acetamide was the first oxazolidinone to be developed and approved for clinical use. Linezolid is a synthetic antibiotic used for the treatment of serious infections caused by Gram-positive bacteria that are resistant to several other antibiotics. Linezolid is active against most *Gram-positive bacteria* that cause diseases including *streptococci*, vancomycin-resistant enterococci (VRE), and methicillin-resistant *Staphylococcus aureus* (MRSA). The main indication of linezolid is the treatment of severe infections caused by Gram-positive bacteria that are resistant to other antibiotics; it should not be used against bacteria that are sensitive to drugs with a narrower spectrum of activity, such as penicillin's and cephalosporin's. In both the popular press and the scientific literature, linezolid has been called a "reserve antibiotic"—one that should be used sparingly so that it will remain effective as a drug of last resort against potentially intractable infections.

Keywords: Linezolid, organic impurities, stress degradation, RP -HPLC.





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INTRODUCTION

Linezolid protein synthesis inhibitor which is a synthetic antibacterial agent of the oxazolidinone class. The chemical name for linezolid is (S)-N-[[3-[3-Fluoro-4-(4-morpholinyl)phenyl]-2-oxo-5-oxazolidinyl] methyl]-acetamide. Linezolid is indicated for the treatment of nosocomial pneumonia caused by *Staphylococcus aureus* (methicillin-susceptible and -resistant isolates) or *Streptococcus pneumoniae*. It is indicated for the treatment of complicated skin and skin structure infections, including diabetic foot infections, without concomitant osteomyelitis, caused by *Staphylococcus aureus* (methicillin-susceptible and -resistant isolates), *Streptococcus pyogenes*, or *Streptococcus agalactiae*. It has not been studied in the treatment of decubitus ulcers [1-2]. To reduce the development of drug-resistant bacteria and maintain the effectiveness of linezolid and other antibacterial drugs, it should be used only to treat or prevent infections that are proven or strongly suspected to be caused by susceptible bacteria. When culture and susceptibility information are available, then it should be considered in selecting or modifying antibacterial therapy. In the absence of such data, local epidemiology and susceptibility patterns may contribute to the empiric selection of therapy.

Linezolid is a white to off white crystalline powder that is soluble in chloroform and slightly soluble in methanol, practically insoluble in n-Hexane. Linezolid is formulated as injection for infusion administration. Linezolid injection contains 2 mg/mL and the following inactive ingredients: lactose monohydrate, corn starch, hydroxypropylcellulose, microcrystalline cellulose, sodium starch glycolate, and magnesium stearate. The film coating for the 14 mg tablet is made of hypromellose, titanium dioxide, talc, polyethylene glycol and indigo carmine aluminum lake. In addition to these, the 7 mg tablet film coating includes iron oxide yellow [3-5]. As per the literature survey several methods have been reported for the estimation of Linezolid and its organic impurities. The present proposed method estimates Teriflunomide and its organic impurities in a simple and economical process. The main aim of this method was to determine and validate the Linezolid based on International Conference on Harmonization [6-8] guidelines. This method was made use of a reproducible procedure for the quantitative analysis of drug samples as injection dosage form and drug substances. Hence in the present study we attempted to develop a simple method for the estimation of Linezolid and its related impurities in pharmaceutical formulation of injection and drug substances. The general information, molecular structure of Linezolid and its organic impurities in the study are given in Table 1 and 2.

INSTRUMENTS, MATERIALS AND METHODS

Instrumentation

The separation and estimation of Linezolid with organic impurities on a HPLC. The Cosmosil 5C18 MS-II column (250 mm × 4.6 mm; 5 μm Make: Waters) using mobile phase-A in the composition of buffer pH 6.8 and Mobile phase-B in the ratio of 89:11 (v/v) and mobile phase-B as a mixture of acetonitrile and tetrahydrofuran in the ratio of 95:5 (v/v) at a flow rate of 1.0 mL/min in gradient elution (MP-A: 25 min, 90%; 55 min, 65%; 62 min, 50%; 75 min, 22%; 78 min, 22%; 79 min, 100% & 90 min, 100%). A 10-μL fixed volume sample was injected for the analysis using a with an auto injector and PDA detector. An analytical balance was used for weighing the standards and samples. pH of the mobile phase was adjusted using a digital pH meter. A photo stability chamber was used for the sample stress. A water system was (Make: Millipore) used for the preparing the diluent and mobile phase preparations [9-10].

Materials (Chemicals, reagents, standards and samples)

The active pharmaceutical ingredient Linezolid with 99.1% purity and its organic impurities were obtained from Sakam private limited. The marketed formulation of Linezolid injection was purchased in a local pharmacy. Analytical laboratory reagent grade Sodium dihydrogen phosphate (NaH_2PO_4), Triethylamine ($\text{C}_6\text{H}_{15}\text{N}$) and Tetrahydrofuran ($\text{C}_4\text{H}_8\text{O}$) were purchased from SD Fine Chem. Limited, Mumbai. HPLC grade acetonitrile, Methanol and water were purchased from Merck Chemicals, Mumbai, and 0.45-μm PVDF filters were used for filtration of samples and purchased from Millipore (India).



**Chandra Sekhar et al.,****Chromatographic Conditions**

A mobile phase system consisting of buffer, tetrahydrofuran and acetonitrile and separation was achieved with gradient elution mode. The flow rate was 1.0 mL/min. The injection volume was 10 µL. The eluent was monitored by the photo diode array detector (PDA) from 200 to 400 nm, and chromatograms were extracted at the wavelengths of 254 nm. The total run time was 90minutes.

Preparation of Solutions**For Method Development**

Optimized separation was achieved on aCosmosil5C18 MS-II column (250 mm×4.6 mm; 5 µmMake:Waters) using mobile phase-Ain the composition of buffer pH 6.8 and mobile phase-B in the ratio of 89:11 (v/v) and mobile phase-B as mixer of acetonitril and tetrahydrofuran in the ratio of 95:5(v/v) at a flow rate of 1.0 mL/min in gradient elution(MP-A:25min,90%;55min,65%;62min,50%;75min,22%;78min,22%;79min,100%& 90min,100%). UV detection was carried out at a wavelength of 254 nm.

Preparation of buffer

Weight and dissolve 3 g of sodiumdihydrogen phosphate in 1000 mL of water, adjust the pH of the solution to 6.8 with diluted triethyl amine solution, mix well and degas.

Preparation of Mobile phase-A

Mix buffer and mobile phase-B in the ratio of 89: 11 (% v/v) respectively and degas.

Preparation of Mobile phase-B

Mix Acetonitrile and Tetrahydrofuran in the ratio of 95: 50 (% v/v) respectively and degas.

Preparation of Blank solution

Mix the water and methanol in the ratio of 70:30(%v/v) respectively.

Preparation of standard solution

First 10 mg of standard drug Linezolidwas weighed accurately and then put in a 100-mL volumetric flask. The drug was dissolved in diluent. Then the final volume was made up to 100 mL with diluent. Further 1 mL of this solution to 25 mL of volumetric flask.Linezolid standard stock solution of 4.0 µg/mL.

Preparation of sample solution

Taken 4 ml of Linezolid transfer into 10 mL volumetric flask and dilute to volume with diluent and mix well. Sample solution containing 800 µg/mL Linezolid.

For Method Validation**System suitability and system precision**

System suitability tests were carried out on a freshly prepared standard solution (800 µg/mL) of the Linezolid andorganic impurities to scrutinize the various optimized parameters such as retention time, % of relative standard deviation, tailing factor and USP plate count.

Specificity: (Blank, Placebo and Impurity Interference)

Specificity tests were carried out on a freshly prepared blank, placebo, individual impurities and spiked sample with organic impurities (800 µg/mL) of the Linezolid and to optimize the parameters such as blank, placebo and individual interference at retention time of Linezolid.



**Chandra Sekhar et al.,****Precision**

Precision was determined using six spiked sample solution containing (800 µg/mL) of Linezolid and its organic impurities that were prepared and analyzed in the optimized method conditions. For intraday precision the solutions were prepared and analyzed six times on the same day. Peak area responses of six replicate analyses were calculated in terms of relative standard deviation (RSD).

Ruggedness

Ruggedness was determined using six spiked sample solution containing (800 µg/mL) of Linezolid and its organic impurities that were prepared and analyzed in the optimized method conditions. For interday precision the solutions were prepared and analyzed six times on the different day, different instrument, different analyst and different column. Peak area responses of six replicate analyses were calculated in terms of relative standard deviation (RSD).

Limit of Detection, Limit of Quantification and Limit of Quantification Precision

Determined the limit of detection and quantification for Linezolid and its organic impurities by deriving the concentration which will give signal to noise ratio between 2.0 to 3.0 for limit of detection and which will give signal to noise ratio between 10 to 30 for limit of quantification. Determined precision by preparing the solution having impurities and Linezolid at about limit of quantification level and injected six times into the chromatographic system and calculated in terms of relative standard deviation (RSD).

Linearity and Range

Linearity study was determined with calibration curves were prepared with six concentration range of LOQ to 150% level for Linezolid and its organic impurities. The solutions were analyzed in optimized conditions. The data of peak area vs concentration were analyzed using linear least square regression.

Recovery

The standard addition for Linezolid and its organic impurities method was carried out for determining the accuracy of the method. For this LOQ 80%, 100% and 120% level concentrations were spiked into known concentrations. Accuracy was determined by comparing the difference between the spiked value and the actual found value.

Robustness

Robustness of the proposed method was tested by slight variation in optimized method conditions. Change in ±5 mL variation in mobile phase organic, ±0.2 pH modifier, ±0.1 flow rate, and ±5°C column oven temperature was studied. In each of the changed conditions, standard solutions containing 4 µg/mL Linezolid and spiked sample containing 800 µg/mL of Linezolid and organic impurities were analyzed in optimized method conditions. % relative standard deviation, tailing factor, theoretical plate count value.

For Force degradation Studies**Acid Hydrolysis**

Accurately transfer 4 mL of sample solution into 10 mL volumetric flask, add 0.1N hydrochloric acid solution and the solution was heated on water bath for 4hrs at 80°C and cool the solution at room temperature. The sample solution was neutralized with equal volume of 0.1N sodium hydroxide solution and diluted to volume with diluent and mix well. Sample solution containing 800 µg/mL of Linezolid was obtained. The solution was analyzed in the developed method conditions and calculated impurity level and peak purity.

Base Hydrolysis

Accurately transfer 4 mL of sample solution into 10 mL volumetric flask, add 0.1N sodium hydroxide solution and the solution was heated on water bath for 4hrs at 80°C and cool the solution at room temperature. The sample solution was neutralized with equal volume of 0.1N hydrochloric acid solution and diluted to volume with diluent and mix



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well. Sample solution containing 800 µg/mL of Linezolid was obtained. The solution was analyzed in the developed method conditions and calculated impurity level and peak purity.

Oxidation

Accurately transfer 4 mL of sample solution into 10 mL volumetric flasks, add 2 mL of 3% H₂O₂ solution and the solution kept at room temperature for 24 hours and diluted to volume with diluent and mix well. Sample solution containing 800 µg/mL of Linezolid was obtained. The solution was analyzed in the developed method conditions and calculated impurity level and peak purity.

Photolytic: (For Visible – 1.2 million lux hours and UV – 200 watt/hours/m²)

Accurately transfer 4 mL of exposed sample solution into 10 mL volumetric flasks and diluted to volume with diluent and mix well. Sample solution containing 800 µg/mL of Linezolid was obtained. The solution was analyzed in the developed method conditions and calculated impurity level and peak purity.

Thermal (80°C for 6 hours)

Accurately transfer 4 mL of exposed sample solution into 10 mL volumetric flasks and diluted to volume with diluent and mix well. Sample solution containing 800 µg/mL of Linezolid was obtained. The solution was analyzed in the developed method conditions and calculated impurity level and peak purity.

Humidity (90% RH for 7 days)

Accurately transfer 4 mL of exposed sample solution into 10 mL volumetric flasks and diluted to volume with diluent and mix well. Sample solution containing 800 µg/mL of Linezolid was obtained. The solution was analyzed in the developed method conditions and calculated impurity level and peak purity.

Method Validation

The method was validated as per ICH guideline Q2 (R1) "Validation of Analytical Procedures"

RESULTS AND DISCUSSION**For Method Development**

The aim of the present work was to develop a simple, specific, precise and accurate reverse phase-HPLC-UV method for the quantification of Linezolid and its organic impurities in pharmaceutical formulations of tablets and drug substances. A literature survey reveals that no method was reported previously for the separation, qualitative and quantitative analysis of Linezolid and its organic. Hence the attempt made here is novel and has significant importance in simultaneous detection and quantification of Linezolid and its organic impurities. The mobile phase was confirmed by change in different solvent ratios, expected peak shape, and resolution achieved using the mobile phase compositions (Mobile phase-B-950 mL of acetonitrile and 50 mL of tetrahydrofuran & Mobile phase-A-895 mL of buffer and 110 mL of mobile phase-B. The mobile phase was pumped at a flow rate of 1.0 mL/min in isocratic elution. UV detection was carried out at a wavelength of 254 nm and separation was achieved on a Cosmosile, 5C18 column (250 mm×4.6 mm; 5 µm). In the optimized conditions, well retained, resolved, and symmetric peaks are observed in the standard chromatogram containing 4 µg/mL Linezolid and its organic impurities. The standard chromatogram obtained in the optimized conditions is given in Figure 1. The blank analysis was performed by analyzing the mobile phase and it confirmed that no detection was observed in the blank chromatogram in Figure 2. The placebo analysis was performed by analyzing the mobile phase and it confirmed that no detection was observed in the placebo chromatogram in Figure 3. The spiked sample analysis was performed by analyzing the mobile phase and it confirmed that well retained and resolution was observed in the spiked chromatogram. This proved that the method developed was specific and no blank and placebo interference was observed in the chromatogram.





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System suitability and system precision

Prior to validation of the developed method, repeatability and system suitability were determined at standard solution concentrations of 4 µg/mL of Linezolid. The solutions were injected and were analyzed in the developed method conditions in six. The system suitability conditions like plate count, tailing factor, % relative standard deviations were determined and found to be within the acceptance limits. Hence the developed method was found to be reproducible and all the system suitable parameters were within the acceptable limits and results given below in Table (4, 5).

Specificity: (Blank, Placebo and Impurity Interference)

Specificity of blank, placebo, individual impurities and spiked sample solutions injected and analyzed in developed method conditions. The specificity conditions like blank, placebo interference at retention of Linezolid and its organic impurities was determined and it was demonstrated the blank, placebo, individual impurities are well separated from each other. Hence the developed method was found to be specific.

Precision

Precision study was demonstrated by preparing six spiking test sample solutions with organic impurities at concentrations 800 µg/mL of Linezolid. The solution was injected and analyzed in developed method conditions. Determined the related substances of these samples and evaluated the precision of the method by computing the % of relative standard deviation of the Linezolid and organic impurities and found to be within the acceptance limits. Hence the developed method was found to be precise and results given below in Table (5).

Ruggedness

Ruggedness study was demonstrated for different analyst, different day, different instrument and different column by preparing six spiking test sample solutions with organic impurities at concentrations 800 µg/mL of Linezolid. The solution was injected and analyzed in developed method conditions. Determined the organic impurities of these samples and evaluated the ruggedness of the method by computing the % of relative standard deviation of the Linezolid system suitability and resolution for organic impurities. All the obtained results are well within the limits. Hence the developed method was found to be rugged results given below in Table (6).

Variation in Flow rate: ±0.2 mL/min, Variation in temperature: ±5°C, Variation in pH : ±0.2

Limit of Detection, Limit of Quantification and Limit of Quantification Precision

Determined the limit of detection and limit of quantification for Linezolid and its organic impurities by deriving concentration which will give signal to noise ratio between 2.0 to 3.0 for limit of detection and which will give signal to noise ratio not less than 10 for limit of quantification. Determined the precision by preparing solution having Linezolid and its organic impurities about limit of quantification level and injected in developed method conditions. Calculated the % of relative standard deviation of the Linezolid and its organic impurities and found to be within the acceptance limits. Hence the developed method was found to be capable to detect the concentration level as well as quantification concentration level [11, 12].

Linearity and Range

Demonstrated the linearity of detector response of organic impurities method, prepared the linearity solutions for Linezolid and its organic impurities with concentration range from LOQ% to 120% level and injected in developed method conditions. Plotted graph to concentration versus peak area. Hence the method is found to be linear and range within the concentration range studied. The linearity results are given below in table 9 and calibration curves shown in Figure 4, 5, 6.

Accuracy

Accuracy of the method was determined by spiked recovery studies. For this accuracy of the test method by preparing recovery sample solutions (i.e spiking test sample with organic impurities and Linezolid at the levels of LOQ%, 100% and 150%). The accuracy sample solutions were injected in developed method conditions. The

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percentage recovery was found to be acceptance limit of 80-120%. Hence the method is accurate and results are given below in table 10.

Robustness

Robustness was tested by analyzing the standard solution and spiked sample solution in the optimized conditions that were changed deliberately (i.e mobile phase composition, pH variation, and column oven temperature and flow rate). The percentage change in each changed condition was calculated complete system suitability and RRT for organic impurities. This confirms that a small change in the analytical conditions did not influence the chromatographic separation and detection of Linezolid and its organic impurities. Hence the method was found to be robust and results given below in Table 11.

Forced degradation Studies

The drug product was exposed to different stress conditions and was analyzed in the optimized conditions and the results were compared with those of an unstressed sample vs stressed condition samples. The percentage degradation was found in oxidation degradation study about 27.140 and no degradation was observed in acid, base hydrolysis, photolytic, thermal and humidity. These additional compounds were not observed in the drug product sample of unstressed chromatogram. Both the impurities and the degradation products were successfully separated in the optimized conditions and hence the method is stability indicating and can separate and quantify the potential impurities in Teriflunomide. The forced degradation results are given in Table 12 and degradation chromatograms given below in figure 4, 5, 6, 7, 8, 9, 10.

CONCLUSION

A simple, validated, and fast stability indicating RP-HPLC method is established for quantification of Linezolid and its organic impurities. In the literature no method was found to be established for the simultaneous quantification of Linezolid and its organic impurities. Hence the method represents the first report about a stability indicating method for the determination of Linezolid and its organic impurities. The proposed method achieves satisfactory separation of Linezolid from impurities and the degradation products, an extended linear range, and rapid analysis time. A high recovery of Linezolid in formulation was obtained. The proposed method ensured precise and accurate determination of Linezolid in pharmaceutical formulations. The excipients present in the formulation were not interfering in the method. Hence the method is simple, convenient, and suitable for analyzing Linezolid and its organic impurities in pharmaceutical formulations of infusion and drug substances in the presence.

REFERENCES

1. Laporte CM, Cruz-Espindola C, Thungrat K, Schick AE, Lewis II TP, Boothe DM. Quality assessment of fluconazole capsules and oral suspensions compounded by pharmacies located in the United States. *Am J Vet Res.* 2017; 78(4):421-432.
2. Nair S, Vanathi M, Ganger A, Tandon R. Ocular Graft versus Host Disease: A Review of Clinical Manifestations, Diagnostic Approaches and Treatment. *Open J Ophthalmol.* 2016; 125:325-335.
3. Bayas A, Mäurer M. Teriflunomide for the treatment of relapsing–remitting multiple sclerosis: patient preference and adherence. *Patient Prefer and Adherence.* 2015; 9:265-279.
4. Miller AE. Teriflunomide in multiple sclerosis: an update. *Neurodegener Dis Manag.* 2017; 7(1):9-29.
5. Leibowitz SM, Yan J. NF- κ B Pathways in the Pathogenesis of Multiple Sclerosis and the Therapeutic Implications. *Front MolNeurosci.* 2016; 9:84. (doi: 10.3389/fnmol.2016.00084).
6. Nakahara J, Maeda M, Aiso S, Suzuki N. Current concepts in multiple sclerosis: autoimmunity versus oligodendroglipathy. *Clin Rev AllergImmu.* 2012; 42(1):26-34.
7. Lublin FD, Reingold SC. Defining the clinical course of multiple sclerosis results of an international survey. *Neurology.* 1996; 46(4):907-911.





Chandra Sekhar et al.,

8. Heine M, van de Port I, Rietberg MB, van Wegen EE, Kwakkel G. Exercise therapy for fatigue in multiple sclerosis. The Cochrane Library. 2015, 22-31.
9. Devi TP, Setti A, Srikanth S, Nallapeta S, Pawar SC, Rao JV. Method development and validation of paracetamol drug by RP-HPLC. J Med Allied Sci. 2013; 3(1):8-21.
10. Aguilar MI. Reversed-phase High-Performance Liquid chromatography. Springer New York. 2004, 9-22.
11. Williams P, Biehl ER. High-pressure liquid chromatographic determination of corticosteroids in topical pharmaceuticals. J Pharma Sci. 1981, 530-534.
12. International Conference on Harmonization (ICH); Validation of analytical procedures: Methodology, Q2B (CPMP/ICH/281/95), 1995. Available at: <http://www.ich.org>.

Table 1: General Information for Teriflunomide

Recommended International Non-proprietary Name	:	Linezolid
Chemical Name (s)	:	(S)-N-[[3-[3-Fluoro-4-(4-morpholinyl)phenyl]-2-oxo-5-oxazolidinyl] methyl]-acetamide.
Solubility	:	Soluble in N,N-Dimethylformamide, sparingly soluble in Acetone and insoluble in water.
Physical Characteristics	:	White to off white powder.
Potential isomerism	:	Linezolid contains chiral center and exhibits optical isomerism and controlled by angle of rotation with limit of -14.5° to -16.5°. The other potential isomer (R-isomer) is controlled to not more than 0.15%.
Solubility in different solvents at about 25°C	:	Soluble in chloroform, slightly soluble in methanol & practically insoluble in n-Hexane.
pH [1% w/v Aqueous Suspension] at about 25°C	:	About 5.0
Partition coefficient	:	About (+) 0.55
Hygroscopicity	:	Non- Hygroscopic

Table 2: Molecular Structures for Linezolid and Organic Impurities

Name	Linezolid	Linezolid Impurity-A	Linezolid Impurity-B
Structure			
Chemical name	(S)-N- [[3-[3-Fluoro-4-(4-morpholinyl)phenyl]-2-oxo-5-oxazolidinyl] methyl]-acetamide.	(S)-N-[[3-[3-fluoro-4-(4-morpholinyl) phenyl]-2-oxo-5-oxazolidinyl] methyl] amine Hydro chloride.	(R)-N-[3-[(3-fluoro-4-morpholin-4-yl)phenyl] amino]-2-hydroxypropyl] acetamide.
Molecular formula	C ₁₆ H ₂₀ FN ₃ O ₄	C ₁₄ H ₁₈ FN ₃ O ₃ HCl	C ₁₅ H ₂₂ FN ₃ O ₃
Molecular weight	337.35	295.31: 36.5	311.35
Name	Linezolid Impurity-C	Linezolid Impurity-D	Linezolid Impurity-E





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Structure			
Chemical name	(S)-N-[[3-[4-morpholinyl]phenyl]-2-oxo-5-oxazolidinyl] methyl acetamide.	(R)-N-[[3-[3-fluoro-4-morpholinyl]phenyl]-2-oxo-5-oxazolidinyl] methanesulfonate.	(R)-N-[[3-[3-fluoro-4-[4-morpholinyl]phenyl]-2-oxo-5-oxazolidinyl] methyl]acetate
Molecular formula	C ₁₆ H ₂₀ N ₃ O ₄	C ₁₅ H ₁₉ FN ₂ O ₆ S	C ₁₆ H ₁₉ FN ₂ O ₅
Molecular weight	318.35	374.4	338.34

Name	Linezolid Impurity-F	Linezolid Impurity-G	Linezolid Impurity-H
Structure			
Chemical name	N,N-bis(((S)-3-(3-fluoro-4-morpholinophenyl)-2-oxo-oxazolidin-5-yl) methyl) acetamide.	(R)-N-[[3-[3-fluoro-4-[4-morpholinyl]phenyl]-2-oxo-5-oxazolidinyl] methyl] chloride.	(S)-N-[[3-[3-fluoro-4-[4-morpholinyl]phenyl]-2-oxo-5-oxazolidinyl] methyl] benzyl amine hydrochloride.
Molecular formula	C ₃₀ H ₃₅ F ₂ N ₅ O ₇	C ₁₄ H ₁₆ N ₂ O ₃ Cl	C ₂₁ H ₂₅ FN ₃ O ₃ Cl
Molecular weight	615.6	314.74	421.90

Name	Linezolid Impurity-I	Linezolid N-Oxide
Structure		
Chemical name	(S)-5-((benzyl (((S)-3-(3-fluoro-4-morpholino phenyl)-2-oxo-oxazolidin-5-yl) methyl) amino) methyl-3-(3-fluoro-4-morpholino phenyl) oxazolidine-2-one.	(S)-N-[[3-[3-fluoro-4-[4-morpholinyl]phenyl]-2-oxo-5-oxazolidinyl] methyl]acetamide-N-oxide
Molecular formula	C ₃₅ H ₃₉ F ₂ N ₅ O ₆	C ₁₆ H ₂₀ FN ₃ O ₅
Molecular weight	663.74	353.35



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Table 4: System suitability results for Linezolid

Injection No.	Peak Area	% RSD NMT 2.0	Tailing Factor NMT 2.0	Theoretical Plates NLT 2000
1	12191	0.4	1.1	8452
2	12282			
3	12210			
4	12284			
5	12199			
6	12201			

% RSD – Relative standard deviation

Table 5: Precision results for Linezolid & its impurities

S.No	Sample Name	Impurity-A	Impurity-B	Impurity-C	Impurity-D	Acceptance criteria
1	Preparation-1	0.191	0.915	0.205	0.200	The % of Relative standard deviation should be Not more than 10.0%
2	Preparation-2	0.192	0.916	0.201	0.199	
3	Preparation-3	0.191	0.914	0.203	0.198	
4	Preparation-4	0.189	0.910	0.200	0.201	
5	Preparation-5	0.192	0.912	0.199	0.204	
6	Preparation-6	0.190	0.913	0.206	0.199	
Average		0.190	0.913	0.202	0.200	
% RSD		0.8	0.2	1.9	1.3	

S.No	Sample Name	Impurity-E	Impurity-F	Impurity-G	Impurity-H	Acceptance criteria
1	Preparation-1	0.204	0.212	0.199	0.195	The % of Relative standard deviation should be Not more than 10.0%
2	Preparation-2	0.198	0.211	0.195	0.196	
3	Preparation-3	0.199	0.213	0.196	0.198	
4	Preparation-4	0.201	0.214	0.198	0.199	
5	Preparation-5	0.204	0.212	0.196	0.197	
6	Preparation-6	0.203	0.211	0.200	0.199	
Average		0.201	0.212	0.197	0.197	
% RSD		0.8	0.7	1.0	0.6	





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S.No	Sample Name	Impurity-I	N-oxide	Acceptance criteria
1	Preparation-1	0.201	0.181	The % of Relative standard deviation should be Not more than 10.0%
2	Preparation-2	0.199	0.185	
3	Preparation-3	0.197	0.186	
4	Preparation-4	0.201	0.180	
5	Preparation-5	0.200	0.182	
6	Preparation-6	0.203	0.184	
Average		0.200	0.183	
% RSD		0.8	1.1	

Table 6: Ruggedness results for Linezolid & its impurities

S.No	Name of the condition	Resolution	%RSD	Acceptance criteria
1	Normal condition	4.5	0.5	The Resolution between the impurity-D & Impurity-E should be not less than 1.5 The % of Relative standard deviation should be Not more than 10.0%
2	Low Flow rate	4.1	0.6	
3	High Flow rate	4.7	0.3	
4	Low column Temperature	3.1	0.4	
5	High column Temperature	5.0	0.9	
6	Low pH	4.4	0.8	
7	High pH	4.5	0.6	

Table 7: Limit of detection results for Linezolid and its organic impurities

S.No	Name of the component	Concentration	S/N ratio value	Acceptance criteria
1	Linezolid	0.11 µg/mL	2.5	Signal to noise ratio between 2.0 to 3.0
2	Impurity-A	0.06 µg/mL	2.7	
3	Impurity-B	0.06 µg/mL	2.6	
4	Impurity-C	0.06 µg/mL	2.9	
5	Impurity-D	0.06 µg/mL	2.7	
6	Impurity-E	0.06 µg/mL	2.8	
7	Impurity-F	0.09 µg/mL	2.8	
8	Impurity-G	0.05 µg/mL	2.8	
9	Impurity-H	0.06 µg/mL	2.5	
10	Impurity-I	0.04 µg/mL	2.8	
11	N-oxide	0.10 µg/mL	2.9	

Table 8: Limit of quantification results for Linezolid and its organic impurities

S.No	Name of the component	Concentration	S/N ratio value	Acceptance criteria
1	Linezolid	0.36 µg/mL	75	Signal to noise ratio should be not less than 10
2	Impurity-A	0.21 µg/mL	80	





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3	Impurity-B	0.21 µg/mL	95
4	Impurity-C	0.20 µg/mL	90
5	Impurity-D	0.22 µg/mL	54
6	Impurity-E	0.20 µg/mL	65
7	Impurity-F	0.31 µg/mL	51
8	Impurity-G	0.18 µg/mL	81
9	Impurity-H	0.21 µg/mL	92
10	Impurity-I	0.16 µg/mL	79
11	N-oxide	0.38 µg/mL	68

Table 9: Linearity results for Linezolid and its organic impurities

S.No	Linezolid			Impurity-A		Acceptance criteria
	Linearity Level (%)	Concentration (µg/mL)	Peak area	Concentration (µg/mL)	Peak area	
1	LOQ	0.3615	10158	0.2110	8958	The correlation coefficient derived from the least square fit of the data should not be less than 0.99
2	25	1.0127	15259	0.4065	14458	
3	50	2.1408	46875	0.8015	28892	
4	75	3.1517	67721	1.1615	44754	
5	100	4.0568	90458	1.6018	59518	
6	120	4.8125	108218	1.9015	70218	
Correlation Coefficient			0.999	NA	0.999	
Intercept			- 2636.650	NA	377.865	
Slope			22818.54	NA	39645.79	

S.No	Impurity-B			Impurity-C		Acceptance criteria
	Linearity Level (%)	Concentration (µg/mL)	Peak area	Concentration (µg/mL)	Peak area	
1	LOQ	0.5045	13865	0.2015	6541	The correlation coefficient derived from the least square fit of the data should not be less than 0.99
2	25	2.1411	49965	0.4512	13199	
3	50	4.2845	109915	0.8512	24258	
4	75	6.3987	163547	1.2514	36777	
5	100	8.4978	215487	1.6545	47085	
6	120	10.1582	250145	1.9545	56112	
Correlation Coefficient			0.999	NA	0.998	
Intercept			747.55	NA	577.78	
Slope			24963.07	NA	28357.92	

S.No	Impurity-D			Impurity-E		Acceptance criteria
	Linearity Level (%)	Concentration (µg/mL)	Peak area	Concentration (µg/mL)	Peak area	
1	LOQ	0.2215	4415	0.2098	7512	The correlation coefficient





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2	25	0.4312	8225	0.4212	13587	derived from the least square fit of the data should not be less than 0.99
3	50	0.8412	17623	0.8358	25987	
4	75	1.2621	26864	1.2261	38567	
5	100	1.6446	39158	1.6217	51987	
6	120	1.9648	45128	1.9348	64875	
Correlation Coefficient			0.997	NA	0.998	
Intercept			-1871.63	NA	-488.42	
Slope			23980.08	NA	32874.44	

S.No	Impurity-F			Impurity-G		Acceptance criteria
	Linearity Level (%)	Concentration (µg/mL)	Peak area	Concentration (µg/mL)	Peak area	
1	LOQ	0.3098	12517	0.1801	7915	The correlation coefficient derived from the least square fit of the data should not be less than 0.99
2	25	0.4406	17582	0.4011	13518	
3	50	0.8318	34158	0.8015	29458	
4	75	1.2454	48121	1.2215	46125	
5	100	1.6197	60125	1.6015	61012	
6	120	1.9450	76198	1.8950	75453	
Correlation Coefficient			0.998	NA	0.998	
Intercept			1123.60	NA	39506.10	
Slope			37851.69	NA	-1255.64	

S.No	Impurity-H			Impurity-I		Acceptance criteria
	Linearity Level (%)	Concentration (µg/mL)	Peak area	Concentration (µg/mL)	Peak area	
1	LOQ	0.2109	7015	0.1658	6046	The correlation coefficient derived from the least square fit of the data should not be less than 0.99
2	25	0.4312	11985	0.4201	6725	
3	50	0.8245	22157	0.8348	13170	
4	75	1.2408	37145	1.2416	18897	
5	100	1.6354	47925	1.6485	24948	
6	120	1.9450	59457	1.9598	31957	
Correlation Coefficient			0.998	NA	0.998	
Intercept			-897.03	NA	1708.57	
Slope			30386.81	NA	14590.56	

S.No	N-oxide			Acceptance criteria
	Linearity Level (%)	Concentration (µg/mL)	Peak area	
1	LOQ	0.3815	6148	The correlation coefficient derived from the least square fit of the data should not be less than 0.99
2	25	0.4545	5912	
3	50	0.8615	11587	
4	75	1.2498	18958	
5	100	1.6575	25179	





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6	120	1.9718	29947
Correlation Coefficient			0.997
Intercept			-744.64
Slope			15539.77

Table 10: Accuracy results for Linezolid & its organic impurities

S.No	Spiking Level	% Recovery					Acceptance criteria
		Linezolid	Impurity-A	Impurity-B	Impurity-C	Impurity-D	
1	LOQ-1	95.1	106.0	102.5	101.1	109.5	The Individual recovery should be between 80.0 – 120.0 %
2	LOQ-2	106.5	101.5	106.6	101.9	103.4	
3	LOQ-3	105.7	102.4	108.1	106.5	105.1	
4	LOQ-4	103.9	98.8	97.2	94.8	99.2	
5	LOQ-5	107.9	96.2	95.4	96.7	96.4	
6	LOQ-6	98.1	105.0	92.5	93.8	99.5	
7	100% -1	98.9	100.2	100.8	96.5	99.6	
8	100% -2	99.5	99.4	99.3	97.3	99.9	
9	100% -3	99.5	98.9	101.2	95.6	100.8	
10	150% -1	101.5	98.6	96.2	100.1	99.3	
11	150% -2	100.8	98.9	98.2	98.7	100.1	
12	150% -3	99.1	99.7	97.6	98.5	100.9	

S.No	Spiking Level	% Recovery					Acceptance criteria
		Impurity-E	Impurity-F	Impurity-G	Impurity-H	Impurity-I	
1	LOQ-1	101.9	95.1	99.1	100.5	104.1	The Individual recovery should be between 80.0 – 120.0 %
2	LOQ-2	110.1	99.4	102.5	101.8	104.8	
3	LOQ-3	108.2	96.8	106.5	106.1	105.4	
4	LOQ-4	110.9	95.8	99.7	97.1	97.6	
5	LOQ-5	107.5	99.6	105.6	99.5	105.4	
6	LOQ-6	105.1	100.9	100.7	96.6	98.6	
7	100% -1	99.5	100.2	100.7	99.5	98.9	
8	100% -2	98.6	99.4	99.5	99.3	99.9	
9	100% -3	98.7	99.0	98.9	100.7	100.4	
10	150% -1	100.8	100.6	96.2	99.4	99.5	
11	150% -2	99.8	98.9	95.7	99.5	99.5	
12	150% -3	100.1	99.5	96.8	98.9	100.6	

S.No	Spiking Level	% Recovery	Acceptance criteria
		N-Oxide	
1	LOQ-1	106.4	The Individual recovery should be between 80.0 – 120.0 %
2	LOQ-2	107.2	
3	LOQ-3	108.4	
4	LOQ-4	109.1	
5	LOQ-5	108.5	
6	LOQ-6	105.3	



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7	100% -1	99.7
8	100% -2	100.1
9	100% -3	99.2
10	150% -1	99.7
11	150% -2	100.5
12	150% -3	100.9

Table 11: Robustness results for system suitability

S.No	Condition	System Suitability for Linezolid		
		% RSD	Tailing factor	Theoretical plate count
1	Optimized	0.1	1.1	15002
2	MP 1	0.2	1.1	16875
3	MP 2	0.1	1.1	16487
4	COT 1	0.1	1.0	15987
5	COT 2	0.4	1.0	15258
6	FV 1	0.2	1.0	15871
7	FV 2	0.2	1.0	16478
8	pH 1	0.4	1.1	15871
9	pH 2	0.1	1.1	16781

MP 1: Mobile phase composition variation -5%, MP 2: Mobile phase composition variation +5%, COT 1: Column Oven Temperature -5%, COT 2: Column Oven Temperature +5%, FV 1: Flow Variation – 0.1 mL, FV 2: Flow Variation – 0.2 mL, pH 1: pH variation – 0.2 and pH 2: pH variation + 0.2.

Table 12: Forced degradation results

S. No	Stress name and conditions	% Amount remaining	% Amount degraded	Peak Purity	
				Purity Angle	Purity Threshold
1	Undegraded	99.5	0.6	3.862	8.189
2	Acid hydrolysis	98.9	0.8	2.944	7.525
3	Base Hydrolysis	95.1	3.8	1.969	16.839
4	Oxidation	98.9	0.5	0.267	1.409
5	Photolytic Visible	92.5	6.5	3.906	8.182
6	Photolytic UV	99.1	0.6	3.922	8.143
7	Thermal	99.2	0.8	2.160	6.861
8	Humidity	101.4	0.5	4.095	7.770





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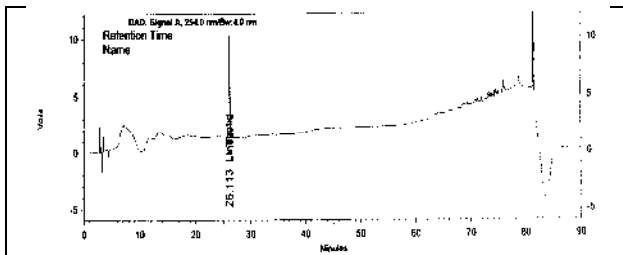


Figure 1: Typical Chromatogram for standard solution

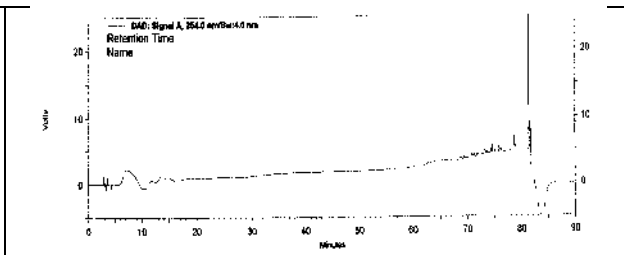


Figure 2: Typical Chromatogram for blank solution

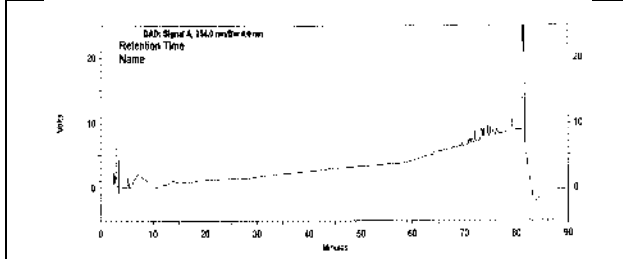


Figure 3: Typical Chromatogram for placebo solution

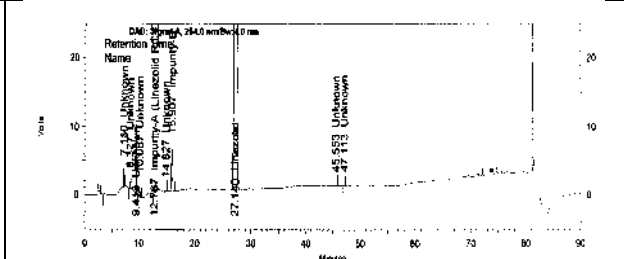


Figure 4: Typical chromatogram for Undegraded sample

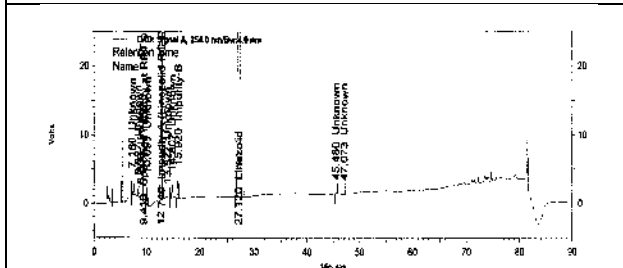


Figure 5: Typical chromatogram for Acid stresses sample

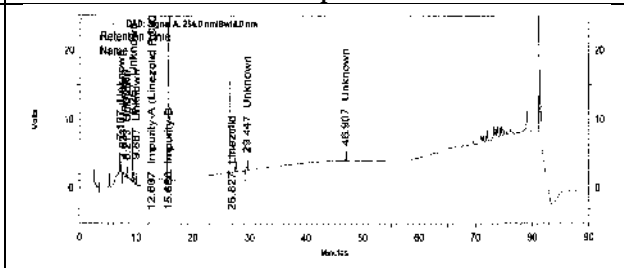


Figure 6: Typical chromatogram for Base stresses sample

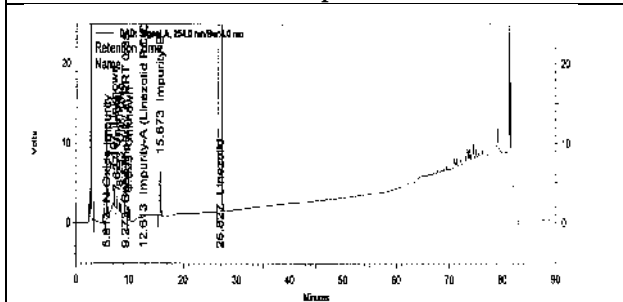


Figure 7: Typical chromatogram for Peroxide stresses sample

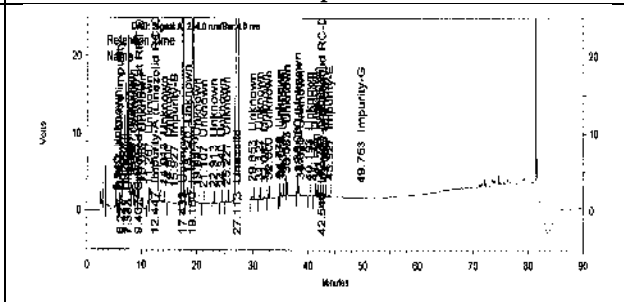


Figure 8: Typical chromatogram for Photolytic Visible stresses sample





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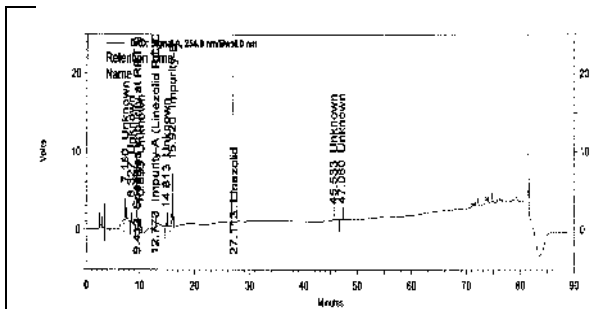


Figure 9: Typical chromatogram for Thermal stresses sample

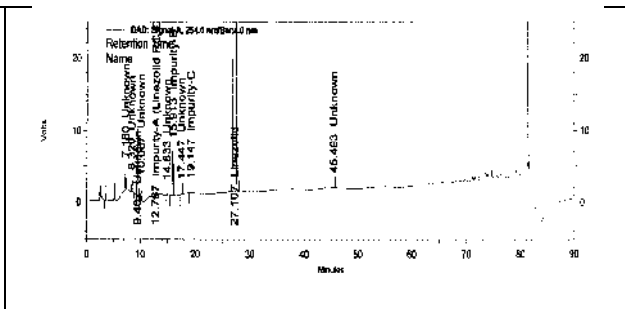


Figure 10: Typical chromatogram for Humidity stresses sample





The Diabetes Dilemma : Integrative Solutions Unveiled

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ABSTRACT

Diabetes mellitus is a chronic disease that usually occurs when blood glucose level is too high in the body which poses significant health risks and economic burdens worldwide. It may leads to increased risk of heart disease, stroke, high blood pressure and narrowing of blood vessels (atherosclerosis). As the prevalence of diabetes continues to rise, there is an urgent need for effective prevention strategies. Diabetes can be well controlled by adopting some lifestyle intervention and alternative interventions. The lifestyle interventions includes nutritional strategies, physical activity and exercise and mind-body approaches. Alternative intervention includes complementary and alternative medicine and community and environmental factors. There is strong evidence that diabetes can be avoided with dietary changes (45%–65%), lifestyle modifications (58%), complementary and alternative medicine (28%–78%), and physical activity (46%). This comprehensive perspective explores the multifaceted nature of diabetes prevention, emphasizing the importance of addressing underlying risk factors such as obesity, sedentary lifestyle and poor dietary habits. In spite of many evidence of their effectiveness, these treatments are still neglected and not widely known by patients and medical practitioners. The present review summarises the integrative approaches for preventing and treating diabetes mellitus. The diabetes can be delayed or prevented in high-risk patients by utilizing the above mentioned approaches through consulting medical practitioners





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Keywords: Diabetes mellitus, Lifestyle intervention, nutritional strategies, physical activity and exercise, mind-body approaches, Alternative intervention, complementary and alternative medicine, community and environmental factors.

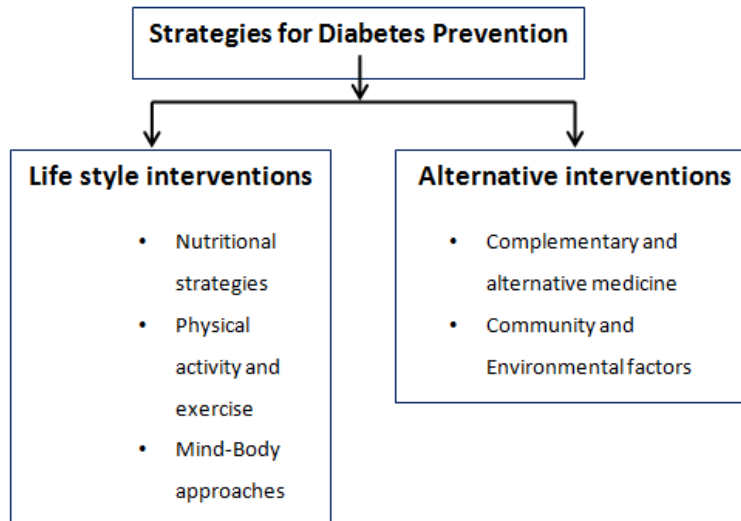
INTRODUCTION

Diabetes mellitus is a metabolic disorder which occurs due to the lack of insulin secretion or insulin resistant in the body. It is majorly classified as insulin-dependent and non insulin-dependent diabetes[1]. Diabetes is one of the leading cause of death and disability worldwide that affects individuals of all ages, genders, and nationalities. Globally, 529 million individuals have diabetes as of 2021 census[2]. Diabetes has become a pandemic in terms of global prevalence, with the 9th edition of the International Diabetes Federation (IDF) reporting a 9% prevalence (463 million adults) in 2019[3]. According to projections, 77 million Indians had diabetes in 2019, and by 2045, that number is predicted to increase to around 134 million[4]. There are many integrative approaches are available for the management and prevention of diabetes mellitus. Recent randomized controlled intervention trials have shown that diet and exercise interventions significantly decreases the incidence of diabetes. Exercise encourages the body to use its glucose more efficiently and decreases blood glucose levels in diabetic individuals under strict control[5]. Diabetes is a diseases for which diet is thought to be one of the key factors in the prevention and progression[6]. In a similar manner, yoga is a traditional Indian mind-body practice that has been linked to better blood sugar level management[7]. Type 2 diabetes mellitus (T2DM) and other chronic illnesses can be prevented and treated with functional food. The biologically active components of functional foods such as polyphenols, terpenoids, flavonoids, alkaloids, sterols, and unsaturated fatty acids have been related to improve physiological health. Increased anti-oxidant, anti-inflammatory, anti-cholesterol, and insulin sensitivity may be associated to a frequent intake of functional foods[8]. Culinary or kitchen herbs in fresh or dried form have been used as a food source throughout the world. The widespread use of kitchen herbs as a traditional herbal remedy for the treatment of diabetes mellitus and its consequences is supported by a number of scientific investigations[9]. Hence the present study focuses on the review of integrative approaches for the prevention of diabetes mellitus.

INTEGRATIVE APPROACHES FOR DIABETES PREVENTION

There are two main integrative approaches for diabetes prevention which involves lifestyle intervention and alternative intervention. Lifestyle intervention includes nutritional strategies, physical activity and exercise and mind-body approaches. Alternative intervention includes complementary and alternative medicine and community and environmental factors.



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LIFESTYLE INTERVENTION

A lifestyle intervention in diabetes prevention involves nutritional strategies, physical activity and exercise, mind-body approaches. In 1980s there was a rise in interest for adopting lifestyle changes to avoid diabetes. Type 2 diabetes (T2D) can be prevented by adopting lifestyle changes as per Diabetes and Nutrition Study Group (DNSG) of the European Association for the Study of Diabetes (EASD)- guidelines 2004[10]. Patients with diabetes mellitus are recommended to follow plant-based diets (PBDs), which are seen as an example of healthful eating habits. The two main pillars of DM management and prevention are diet and lifestyle[11].

Nutritional strategies

Various cardiometabolic risk factors such as blood pressure (BP), glucose-insulin homeostasis, lipoprotein concentrations and function, oxidative stress, inflammation, endothelial health, hepatic function, adipocyte metabolism, cardiac function are clearly influenced by dietary habits[12]. Hence, dietary interventions helps to improve the metabolic illnesses like diabetes and obesity as well as people's quality of life[13]. The typical Mediterranean diet has shown beneficial effect on diabetes and cardiovascular risk factors. The traditional Mediterranean diet involves seasonal, local and natural ingredients. This diet contains a lot of vegetables, whole grain breads, other grains and legumes that have undergone minimal processing have been utilized as the primary source of energy. The secondary source of the diet involves nuts, seeds, and fresh fruits. Dairy products (primarily yogurt and cheese), fish, poultry, and eggs should be moderately consumed. Red meat is consumed infrequently (about once per week) and even wine is moderately consumed, usually with meals[6]. One of the dietary regimens that has been researched the most is the Mediterranean diet. In addition, it is a significant source of fiber, antioxidants, vitamins, minerals, and poly- monounsaturated fatty acids, all of which have numerous health advantages. There's no shortage of proof about its health benefits[14]. The natural nutraceutical contents of the Mediterranean diet (MD), such as pigments, polyphenols, terpenoids, flavonoids, alkaloids, sterols, and unsaturated fatty acids, are biologically active components for functional foods[8].

Physical activity and exercise

Physical activity is important for maintaining physical and mental health of a wellbeing[15]. Regular physical activity is crucial for human growth at every stage of life, as it promotes and preserves health. Positive changes in physiological parameters brought about by exercise are directly associated with an improvement in one's overall health[16]. Numerous health advantages of exercise are relevant to individuals with insulin-dependent and non



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insulin-dependent diabetes. It is essential to understand that during exercise, hypoglycemia and hyperglycemia can both happen, but there are ways to manage these risks[17]. Aerobic exercise, which includes jogging, walking, cycling, and swimming, is the type of exercise that has historically been studied and it leads to bulking of muscles. It has long been recognized as one of the most significant non-pharmacological diabetes therapy option. According to recent research, combined exercise—a combination of aerobic and resistance training—proves to be more advantageous than either training approach alone. Resistance training may increase muscle mass and improve blood glucose uptake by improving insulin sensitivity; these two strategies appear to work in concert through the expression mechanisms of glucose transporter type 4[18]. If a woman has gestational diabetes mellitus (GDM), her chances of developing type 2 diabetes later in life may be nearly ten times higher. Engaging in physical activity can help avoiding GDM and the subsequent onset of Type 2 Diabetes. Exercise before pregnancy has been repeatedly linked to a lower incidence of gestational diabetes mellitus. The moderate aerobic exercise is practiced three days a week for eight to ten weeks during the third trimester. Additionally, excessive weight gain during pregnancy is minimized[19]. No matter how active one is, there is a clear correlation between obesity or incident diabetes and sedentary time (either self-reported or objectively observed). Diabetes risk can double with extended durations of inactivity. According to one study, watching television for an hour raised the incidence of diabetes by 3.4% over 2 to 3 years[20]. As per the study performed by Matthias Li *et. al.*, there is a evidence regarding lifestyle intervention for diabetes prevention. Diabetes can be prevented by proper consultation of dieticians, physicians or other suitable authorities[21].

Mind-body approaches

Mind-body therapies are interventions which are meant to increase the positive effects of the mind on the body, according to the American Academy of Pediatrics (2016). Conventional techniques like meditation and yoga as well as modern western methods like hypnosis, progressive relaxation, autogenic training, mindfulness, biofeedback, relaxation training, and psychiatric therapies are followed for prevention of diabetes[22]. Several studies have shown that meditations along with yoga are helping persons with type 2 diabetes to control their blood sugar levels. It was discovered that patients with T2D showed gradual improvements in fasting blood glucose (FBG), glycated haemoglobin (HbA1c), postprandial blood glucose (PPBG), total cholesterol (TC), low-density lipoprotein cholesterol (LDL-C), and high-density lipoprotein cholesterol (HDL-C), by performing meditation[23]. Meditation techniques—such as focusing on the body, lying down on the ground, or taking a leisurely walk by being aware of the surroundings—as well as paying close attention to what one is doing or feeling at any given time are the examples of mindfulness exercises. Although mindfulness and meditation are interconnected, they are not the same. Buddhist lineages have been using the idea of mindfulness for 2,500 years[24]. The yoga intervention improved blood glucose levels and it is very practicable and well-accepted. A yoga practice consists of two parts: poses or asanas and meditation or shavasana. Poses or asanas includes sitting, standing, twists, restorative postures. Yoga contributes to mindfulness by making the practitioner more aware of their body and it emphasise on breath control, holding poses, and meditation. It also help the people to identify emotional stress and respond with more useful coping mechanisms, thus mindfulness helps in the treatment of diabetes[25].

ALTERNATIVE INTERVENTION

An alternative intervention involves complementary and alternative medicine as well as community and environmental factors.

Complementary and alternative medicine

Approaches from complementary and alternative medicine have become more popular in recent years. Complementary medicine is used in addition to established therapies, but alternative medicine is used in place of them. A recent study found that there was 50–80% increase in the usage of complementary medicine. Numerous chronic diseases have been treated and prevented with its help. It's interesting to note that about 80% of medicine practiced in underdeveloped nations is complementary and alternative medicine. The focus on broadening the scope of conventional allopathic therapy has given rise to a new field called integrative medicine. The goal of integrative medicine is to treat chronic disease like diabetes with natural, minimally invasive methods[26]. Additionally, kitchen



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herbs are widely utilized in traditional herbal medicine to treat diabetes mellitus and its complications. Certain culinary herbs, such as clove, anise, fenugreek, turmeric, cumin, flaxseeds, rosemary, green cardamom, and chamomile, shows promising anti-diabetic property[9]. Today, medicinal plants can also be utilized to treat diabetes mellitus because of their increased cost-effectiveness and ability to prevent some pharmacological adverse effects. Through the AMPK signaling pathway, certain herbal plants have been shown to ameliorate insulin resistance and hyperglycemia. Examples of such herbs include *Nigella sativa*, *Punica granatum*, *Berberine*, *Curcumin*, *Moringa oleifera*, and *Portulaca oleracea*. The application of medicinal plant therapy in the management of diabetes mellitus indicates the significance of this treatment and preventative strategy. Numerous herbs have demonstrated antidiabetic effects through a variety of methods, including reducing inflammation and oxidative stress, boosting insulin sensitivity and glucose absorption, and controlling insulin-induced signaling in various organs. Additionally, a wide variety of herbs with significant phytochemical contents, low toxicity, and inexpensive cost are easily found around the world. However, additional clinical research is required to validate the beneficial effects of these formulations produced from plants in the treatment and management of diabetes[27].

Community and environmental factors

Community and environmental factors are also one of the intervention for the prevention of diabetes.

Community Factors

Community intervention focus on, the complete population residing in a certain area outside of clinical or healthcare settings are referred to as community-based interventions. Community factors includes three requirements which have to be met in order to have a sufficient and successful diabetes prevention intervention. At first, the interventions target the general public, for example by educating the public about diabetes. The second is the application of predetermined theoretical frameworks in intervention design. Third, most of the underlying pathogenic mechanisms should be addressed by the therapies. One of the effective strategy for the primary prevention of diabetes is public education[28].

Environmental Factors

The environmental factors like green spaces, open spaces, also plays a role in prevention of diabetes. In current scenario, crime, social disorders, and unsafe neighbourhood can incite social isolation and fear in the people and inhibit physical activity. There is a evidence to show that traffic, transportation have an impact on physical activity and local pollution levels. Exercise will be discouraged by air pollution, and mental health and sleep may be negatively impacted by noise. In addition to having a negative impact on blood lipid levels, air pollution and road noise may also increase the risk of T2DM and blood pressure. The green spaces, open spaces, green parks will motivate a person for physical activity and social interaction which ultimately leads to prevent diabetes[29]. Green areas and natural surroundings are good for one's mental health and wellbeing[30].

CONCLUSION

This review focused on integrated approaches for diabetes prevention. Effective lifestyle changes, such as weight loss counseling, adopting a Mediterranean diet rich in fruits, vegetables, and tree nuts, and engaging in aerobic exercise such as jogging, cycling, swimming, and walking, are the cornerstones in the prevention of diabetes. Exercise increases insulin sensitivity, which improves the body's usage of insulin. Mind-body approaches which involves yoga and meditation are also a strategy for diabetes prevention. Alternative approaches such as complementary and alternative medicines like herbal remedies and kitchen herbs like garlic, ginger, fenugreek, turmeric, cumin, flaxseeds, clove, aniseed, rosemary, green cardamom are having promising anti-diabetic property. Environmental factors like green spaces, open spaces, green parks also improves one's overall health and prevent diabetes. The primary objective of this review is to address diabetes mellitus through integrative approaches with the goal of both preventing and treating the condition, while also emphasizing the importance of maintaining a high quality of life.





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REFERENCES

1. Harreiter J, Roden M. Diabetes mellitus: Definition, classification, diagnosis, screening and Prevention (update 2023). Wiener klinische Wochenschrift 2023;135(suppl 1): 7-17.
2. Ong KL, Stafford LK, McLaughlin SA, Boyko EJ, Vollset SE, Smith AE, Dalton BE, Duprey J, Cruz JA, Hagins H, Lindstedt PA. Global, regional, and national burden of diabetes from 1990 to 2021, with projections of prevalence to 2050: a systematic analysis for the Global Burden of Disease Study 2021. The Lancet 2023;402:203-234.
3. Sun H, Saeedi P, Karuranga S, Pinkepank M, Ogurtsova K, Duncan BB, et al. Erratum to Idf diabetes atlas: Global, regional and country-level diabetes prevalence estimates for 2021 and projections for 2045 [diabetes res. Clin. pract. 183 (2022) 109119]. Diabetes Research and Clinical Practice 2023;183:110945.
4. Mohan V, Pradeepa R. Epidemiology of type 2 diabetes in India. Indian Journal of Ophthalmology 2021;69:2932-2938.
5. Sato Y. Diabetes and life-styles: Role of Physical Exercise for primary prevention. British Journal Of Nutrition 2000;84(Suppl 2):187-90.
6. Martín-Peláez S, Fito M, Castaner O. Mediterranean diet effects on type 2 diabetes prevention, disease progression, and related mechanisms a Review. Nutrients 2020;12:1-15.
7. Chattopadhyay K, Mishra P, Manjunath NK, Harris T, Hamer M, Greenfield SM, et al. Development of a yoga program for type-2 diabetes prevention (yoga-DP) among high-risk people in India. Frontiers in Public Health 2020;8.
8. Alkhatib A, Tsang C, Tiss A, Bahorun T, Arefanian H, Barake R, et al. Functional Foods and lifestyle approaches for diabetes prevention and management. Nutrients 2017;9:2-18.
9. Akhter S. Low to no cost remedies for the management of diabetes mellitus; global health concern. Journal of Diabetes & Metabolic Disorders 2021;20:951-962.
10. Uusitupa M, Khan TA, Viguioliuk E, Kahleova H, Rivellese AA, Hermansen K, et al. Prevention of type 2 diabetes by lifestyle changes: A systematic review and meta-analysis. Nutrients 2019;11:1-22.
11. Pollakova D, Andreadi A, Pacifici F, Della-Morte D, Lauro D, Tubili C. The impact of vegan diet in the prevention and treatment of type 2 diabetes: A systematic review. Nutrients 2021;13:1-13., 2021.
12. Mozaffarian D. Dietary and policy priorities for cardiovascular disease, diabetes, and obesity. Circulation 2016;133:187-225.
13. Li M, Jeeyavudeen MS, Arunagirinathan G, Pappachan J. Is type 2 diabetes mellitus a behavioural disorder? an evidence review for type 2 diabetes mellitus prevention and remission through lifestyle modification. European Endocrinology 2023;19:7-15.
14. Vitale M, Masulli M, Calabrese I, Rivellese A, Bonora E, Signorini S, et al. Impact of a Mediterranean dietary pattern and its components on cardiovascular risk factors, glucose control, and body weight in people with type 2 diabetes: A real-life study. Nutrients 2018;10:1-12.
15. Dhuli K, Naureen Z, Medori MC, Fioretti F, Caruso P, Perrone MA, Nodari S, Manganotti P, Xhufi S, Bushati M, Bozo D. Physical activity for health. Journal of Preventive Medicine and Hygiene 2022;63:(2 suppl 3):E150-E159.
16. Miko HC, Zillmann N, Ring-Dimitriou S, Dorner TE, Titze S, Bauer R, "Auswirkungen von Bewegung auf die Gesundheit. Das Gesundheitswesen 2020;82(S 03):S184-S195.
17. Lumb A. Diabetes and exercise. Clinical Medicine 2014;14:673-676.
18. Sampath Kumar A, Maiya AG, Shastry BA, Vaishali K, Ravishankar N, Hazari A, et al. Exercise and insulin resistance in type 2 diabetes mellitus: A systematic review and meta-analysis. Annals of Physical and Rehabilitation Medicine 2018;62:98-103.
19. Kanaley JA, Colberg SR, Corcoran MH, Malin SK, Rodriguez NR, Crespo CJ, et al. Exercise/physical activity in



**Hamsaveni et al.,**

- individuals with type 2 diabetes: A consensus statement from the American College of Sports Medicine. *Medicine & Science in Sports & Exercise* 2022;54:353-368.
20. Kolb H, Martin S. Environmental/lifestyle factors in the pathogenesis and prevention of type 2 diabetes. *BMC Medicine* 2017;15:1-11.
 21. Cozzolino M, Girelli L, Vivo DR, Limone P, Celia G.A mind-body intervention for stress reduction as an adjunct to an information session on stress management in University Students. *Brain and Behavior* 2020;10:1-8.
 22. Yang H-J, Koh E, Sung M-K, Kang H. Changes induced by mind-body intervention including epigenetic marks and its effects on diabetes. *International Journal of Molecular Sciences* 2021;22:1-15.
 23. Esch T, Kream RM, Stefano GB. Chromosomal processes in mind-body medicine: Chronic stress, cell aging, and telomere length. *Medical Science Monitor Basic Research* 2018;17:134-140.
 24. Janssen M, Heerkens Y, Kuijer W, van der Heijden B, Engels J. Effects of mindfulness-based stress reduction on employees' Mental Health: A Systematic Review. *PLOS ONE* 2018;13:e0191332.
 25. Bock BC, Thind H, Fava JL, Dunsiger S, Guthrie KM, Stroud L, et al. Feasibility of yoga as a complementary therapy for patients with type 2 diabetes: The healthy active and in control (ha1c) study. *Complementary Therapies in Medicine* 2019;42:125-131.
 26. Nieves JP, Baum SJ. A review of the evidence for alternative and complementary medical approaches in the prevention of atherosclerotic cardiovascular disease and diabetes. *Cardiovascular Endocrinology* 2017;6:39-43.
 27. Balbaa M, El-Zeftawy M, Abdulmalek SA. Therapeutic screening of herbal remedies for the management of diabetes. *Molecules* 2021;26:2-18.
 28. Shirvani T, Javadi Z, Azimi S, Shaghghi A, Fathifar Z, Devender Bhalla HD, et al. Community-based educational interventions for prevention of type II diabetes: A global systematic review and meta-analysis. *Systematic Reviews* 2021;10:2-21.
 29. Dendup T, Feng X, Clingan S, Astell-Burt T. Environmental risk factors for developing type 2 diabetes mellitus: A systematic review. *International Journal of Environmental Research and Public Health* 2018;15:1-25.
 30. Marselle MR, Lindley SJ, Cook PA, Bonn A. Biodiversity and health in the urban environment. *Current Environmental Health Reports* 2021;8:146-156.





Comparison of Blood Flow Restriction Training and Resistance Training with Slow Movement Tempo on Muscle Strength and Throwing Capacity of Upper Limb in College Going Cricket Players

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ABSTRACT

Cricket is a sport that constantly calls for a lot of physical stamina and ability, whether bowling, batting or fielding. Resistance training with blood flow helps to gain strength with lighter loads as well to increase muscle strength. The purpose of the study was to compare the impact of resistance training with slow movement tempo and training with blood flow restriction on upper limb throwing ability and muscle strength in collegiate cricket players. 60 subjects were randomly divided into two groups using chit method. Group A included 30 subjects who received blood flow restriction training and Group B included 30 subjects who received resistance training with slow movement tempo. The duration of treatment was 3 days/week. Outcome measures included were 1RM and medicine ball throw. Result was analysed using IBM SPSS version 27 software. For between group analysis Mann-Whitney U test and for within-group pre and post analysis Wilcoxon signed rank test was used. Premean \pm SD for 1 RM for group A and B was 24 ± 5.96 , 24.74 ± 7.60 and post mean \pm SD was 39.96 ± 12.522 , 39.07 ± 10.32 respectively. Premean \pm SD for medicine ball chest pass for group A and B was 205.18 ± 50.94 , 204.4 ± 53.44 and post mean \pm SD was 317.03 ± 69.77 , 286.29 ± 53.21 respectively. There was significant improvement seen in post assessment with p-value (<0.05). The present study concluded that statistically both the treatment





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protocols were effective. But implementation of blood flow restriction training showed clinical improvement in improving muscle strength and throwing capacity of upper limb than resistance training with slow movement tempo.

Keywords: Blood flow restriction training, Strengthening technique, Musculoskeletal conditions, Physiotherapy, Sports Physical therapy.

INTRODUCTION

Cricketers frequently sustain shoulder injuries that can progress to chronic or recurrent conditions [1]. Overuse and impact injuries are prevalent in cricket as a variety of physical tasks, such as sprinting, throwing, batting, bowling, catching, jumping, and diving, are required of the participants [2][3]. Throwing overhead repeatedly extends the anterior joint capsule and tightens the ligamentous and muscular complex of the posterior capsule, resulting in a decrease in internal rotation (IR) and an increase in external rotation (ER) termed as “Gleno-Humeral Internal Rotation Deficit” (GIRD) [4][5][6]. It is crucial to use the scapula-thoracic musculature during the overhead throwing motion [7]. Correct scapular mobility and stability are essential for the shoulder to function effectively [8][9]. These muscles work as force couples to coordinate their activities, giving the scapula stability and mobility [4].

In team sports, anthropometric traits (hand width, grip strength, body size, and proportions), balance, visual acuity, and technique (neuromuscular coordination and timing) to produce an explosive-ballistic throwing motion of high accuracy can all have an impact on throwing precision [10][11][12]. Therefore, it represents a relevant measure, besides throwing velocity, which needs to be observed in assessing throwing performance [10][11][12].

Blood flow restricted (BFR) training, also known as Kaatsu training, was developed in the 1970s and 1980s by Japanese inventor Yoshiaki Sato [13][14][15]. This training approach entails restricting blood flow to a muscle by mechanically compressing the underlying vasculature using an external constricting device, such as a blood pressure cuff or tourniquet. Thus, increases blood collection in the limb muscle's capillary beds distal to the tourniquet. [13][14][15]. Studies have shown that BFR exercise training improved the localised endurance, cardio-respiratory endurance, muscle strength, and hypertrophy [16][17]. Potential reasons for these adaptations include increased duration of metabolic acidosis through the trapping and storage of intramuscular protons (H⁺ ions), hypoxia or preferential recruitment of fast-twitch (FT) muscle fibres, and activation of metabolic sensors [16][17]. The occlusion of lower extremities improving upper-body strength more than a group without BFR supports the theory that there are systemic effects on the body [18][19][20].

An athlete can improve their power and general strength by engaging in resistance training [18][19][20]. One training factor that has been receiving a lot of focus recently is the speed at which each repeat of a resistance exercise is performed [18][19][20]. Usually, the length of a single repetition (measured in seconds) or the movement's velocity (measured in metres per second) determine the movement tempo of a given repetition [18][19][20].

The changes in duration of the movement influence the number of performed repetitions, time under tension, muscle activity and maximal load lifted during resistance exercise [21][22]. Pereira et al. showed that longer durations of the eccentric phase appear to be superior for gaining muscle mass and developing strength in biceps brachii muscle in well-trained men. Davies et al. concluded that fast and moderately slow repetitions produce similar gains in muscle strength. The gold standard for determining muscle strength is the one-repetition maximum (1RM) test [23][24][25]. Therefore, a more appropriate functional measure of upper body strength than the isokinetic internal and external rotation of the shoulder would be the 1RM bench press, an advanced exercise that involves the triceps, anterior deltoids, serratus, and coracobrachialis [26][27]. The Seated Medicine Ball Throw (SMBT), which is feasible in an



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everyday setting, has been used extensively in the literature to measure upper body explosiveness [28][29][30]. The aim of the present study was to compare the effect of blood flow restriction training and resistance training with slow movement tempo on muscle strength and throwing capacity of upper limb in college going cricket players.

MATERIALS AND METHODOLOGY

All cricket players from Parul University, Vadodara, India were recruited in the study. Following an initial screening 60 participants were screened based on inclusion criteria. Cricket players aged between 18-30 years, those who were playing for at least 6 hours/week and who were willing to participate were included in the study. Participants who had recent injuries, playing other sports including cricket, who has gone under recent surgery, having any musculoskeletal disorders, cardiovascular diseases or neurological disorders were excluded. Ethical approval was obtained from Parul University Institutional Ethics Committee for Human Research (PUIECHR/PIMSR/00/081734/4406).

OUTCOME MEASURES

- 1RM- Bench press for strength
[ICC – 0.99, Validity – 0.95]
- Medicine ball chest pass with 3kg for throwing capacity
[ICC – 0.93, Validity – 0.80]

1RM Bench press

Purpose: To measure maximum strength of various muscle and muscle groups.

Equipment required: Free weights (barbells, dumbbells) or other gym equipment.

Pre-test: Test procedure was explained to the subject. Screening for health risks was done and informed consent was taken. Preparation of forms and record of basic information such as name, age, height, body weight, gender, test conditions were taken. Equipment was checked for safety and calibrated if required.

Procedure: It is important to reach the maximum weight without prior fatiguing the muscles. After a warm up, a weight that was achievable was decided. Then after a rest of at least several minutes, the weight was increased and participants tried again. The athlete choose subsequent weights until they could only repeat one full and correct lift of that weight.

Calculation for 1RM was based on the formula derived by Boyd Epley in 1985, which is:

$$1RM = \text{weight} \times (1 + (\text{reps} / 30))$$

80% of 1RM Bench press was recorded.

Medicine ball chest pass in cross leg sitting

Participants were asked to sit on the ground with their legs crossed and back located on the starting line. Then were instructed to throw a 3kg medicine ball as far as possible using their upper body; however, participants were restricted from any activation of their core musculature that would result in observable trunk flexion movement. The distance was recorded from the midpoint of the mark left by the medicine ball on the ground to the starting line. 3 attempts were given with 10 seconds of rest between each throw. The greatest distance was recorded for further analysis.

PROCEDURE

Participants of the present study were recruited from at Parul University, Vadodara, India. Participants fulfilling the inclusion criteria were selected and then asked to sign the written informed consent form and their privacy and confidentiality was maintained. Then the participants were divided into two groups using computer generation method.

Group A: Blood flow restriction group

Group B: Resistance training with slow movement tempo group



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For pre assessment –1RM bench press (3-4 days prior) and medicine ball chest pass in cross leg sitting (1 day prior) was taken.

TRAINING PROTOCOL: 3day/week for 6 conservative weeks

STATISTICAL ANALYSIS

IBM SPSS statistics version 27 was used for the analysis of the data and Microsoft word and excel have been used to generate graphs, pie chart and tables. Descriptive statistical analysis has been carried out. Significance was assessed at 5% level of significance $p < 0.005$ (2-tailed hypothesis test was considered). Non-parametric tests i.e., Wilcoxon test was used to compare two related samples and Mann Whitney test was used to compare two independent samples.

RESULTS

The present study included 60 participants in our study, from which there 54 participants completed the treatment protocol. Within group analysis showed that there was clinical improvement seen in both the Group A and B. P -value for 1 RM found to be 0.002 and 0.0001 for Group A and Group B respectively, which is considered statistically significant ($p < 0.05$). P -value for medicine ball chest pass in cross leg sitting found to be 0.001 and 0.0001 for Group A and Group B respectively, which is considered statistically significant ($p < 0.05$).

Between group analysis showed that Group A had better clinical improvement for 1 RM and medicine ball chest pass in cross leg sitting with mean \pm SD 15.96 \pm 9.35 and 111.85 \pm 56.16 respectively. P -value found to be 0.761 and 0.615 which is not statistically significant (> 0.05). Therefore, present study found that statistically both the treatment were effective and clinically improvement was seen in both the groups after implementation of the interventions.

DISCUSSION

This research aimed to investigate the effect of blood flow restriction training and resistance training with slow movement tempo on upper extremity muscle strength and throwing capacity in cricket players.

According to our findings, there was a significant improvement in both outcomes. In their study, Manini TM et al. also mentioned that while low-intensity BFR exercise causes an immediate elevation in blood GH concentrations, the related trigger for GH secretion is unknown. Lactate is thought to play an important role in regulating exercise-induced GH release. [31] According to Cook CJ et al., the potential of bilateral BFR training applied to the lower body to improve upper body strength increases suggests a systemic process that is not restricted to localised hypoxia or metabolite buildup. Interestingly, despite the reduced intensity, BFR training has been shown to produce equivalent or higher amounts of growth hormone as 70-85% 1RM with no limitation. [32] Although BFR training causes more muscle hypertrophy and growth hormone secretion at lower exercise loads, it causes less muscle injury than high-intensity exercise with no vascular restriction. [33][34].

Disa L. Hatfield et al. [12] stated that the very slow movement velocity led to low frequency fatigue and subsequent decreased rate of force development, resulting in a decreased return in repetition number compared with the volitional speed repetitions. [35].

Force output is also related to the process of motor unit recruitment, motor unit firing frequency, enhanced synchronisation, and needed activation for the amount of cross-sectional area of the muscle, all of which are significant for training-induced improvements in strength and hypertrophy. [36][37] Fast motor units, such as those required for high force output, benefit from training at maximum or near-maximal forces [38] and at a quicker training velocity. [39]. High intensity, short rest resistance training tries to increase time under tension, which leads to an increased anabolic hormone response and, eventually, muscular hypertrophy [85-87] enhanced testosterone response, in instance, results in enhanced protein synthesis and an anabolic state. [40][41][42] which may contribute to



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the increase in strength and muscle hypertrophy caused by resistance training [43]. Moderate to heavy loads, large muscle mass activation, moderate to high repetitions, and short rest periods have been demonstrated to increase muscle androgen receptor content [88], elevate endogenous T [43] and induce an immunological response to promote anabolism and inhibit catabolism, most likely due to higher metabolic demands. Furthermore, the increase of time under tension during the post-activation performance enhancement condition also be attributed to increased phosphorylation of myosin light chains rendering the actin and myosin molecules more sensitive to Ca²⁺ availability [44][45], which would allow the participants to maintain a certain amount of force even in the presence of biochemical changes within the working muscle that lead to fatigue. It also indicates that the increase in TUT was not related to the changes in concentric velocity and power output. [44].

However, the results suggest that blood flow restriction training may be more effective than resistance training with slow movement tempo in terms of improving upper extremity muscle strength and throwing capacity. Therefore, this research project may provide useful information for cricket players and coaches in terms of designing effective training programs to improve upper extremity muscle strength as well as throwing capacity.

CONCLUSION

The present study found that both the techniques were effective. But the implementation of blood flow restriction training showed more clinical improvement in improving muscle strength and throwing capacity of upper limb in college going cricket players.

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REFERENCES

1. Ranson C, Gregory PL. Shoulder injury in professional cricketers. *Physical Therapy in Sport*. 2008 Feb 1;9(1):34-9.
2. Orchard JW, Ranson C, Olivier B, Dhillon M, Gray J, Langley B, Mansingh A, Moore IS, Murphy I, Patricios J, Alwar T. International consensus statement on injury surveillance in cricket: a 2016 update. *British Journal of Sports Medicine*. 2016 Oct 1;50(20):1245-51.
3. Orchard J, Newman D, Stretch R, Frost W, Mansingh A, Leipus A. Methods for injury surveillance in international cricket. *Journal of Science and Medicine in Sport*. 2005 Mar 1;8(1):1-4.
4. Wilk KE, Obma P, Simpson CD, Cain EL, Dugas J, Andrews JR. Shoulder injuries in the overhead athlete. *Journal of orthopaedic & sports physical therapy*. 2009 Feb;39(2):38-54.
5. Bigliani LU, Codd TP, Connor PM, Levine WN, Littlefield MA, Hershon SJ. Shoulder motion and laxity in the professional baseball player. *The American journal of sports medicine*. 1997 Sep;25(5):609-13.
6. Brown LP, Niehues SL, Harrah A, Yavorsky P, Hirshman HP. Upper extremity range of motion and isokinetic strength of the internal and external shoulder rotators in major league baseball players. *The American journal of sports medicine*. 1988 Nov;16(6):577-85.
7. DiGiovine NM, Jobe FW, Pink M, Perry J. An electromyographic analysis of the upper extremity in pitching. *Journal of shoulder and elbow surgery*. 1992 Jan 1;1(1):15-25.
8. Kibler WB. The role of the scapula in athletic shoulder function. *Am J Sports Med*. 1998;26:325-337
9. Kibler WB. The role of the scapula in the overhead throwing motion. *ContempOrthop*. 1991;22:525-532.



**Revati Sunil Pagare et al.,**

10. Kraemer WJ, Ratamess N, Fry AC, et al. Influence of resistance training volume and periodization on physiological and performance adaptations in collegiate women tennis players. *Am J Sports Med* 2000;28:626–33.
11. Marsh DW, Richard LA, Verre AB, Myers J. Relationships among balance, visual search, and lacrosse-shot accuracy. *The Journal of Strength & Conditioning Research*. 2010 Jun 1;24(6):1507-14.
12. Mish FC, editor. Merriam-Webster's collegiate dictionary. Merriam-Webster; 2004.
13. Sato Y. The history and future of KAATSU training. *International Journal of KAATSU Training Research*. 2005;1(1):1-5.
14. American College of Sports Medicine. American College of Sports Medicine position stand. Progression models in resistance training for healthy adults. *Medicine and science in sports and exercise*. 2009 Mar;41(3):687-708.
15. Loenneke JP, Wilson JM, Wilson GJ et al. Potential safety issues with blood flow restriction training. *Scand J Med Sci Sports* 2011; 21(4):510–518.
16. Luebbers PE, Fry AC, Kriley LM, Butler MS. The effects of a 7-week practical blood flow restriction program on well-trained collegiate athletes. *The Journal of Strength & Conditioning Research*. 2014 Aug 1;28(8):2270-80.
17. Fahs, CA, Loenneke, JP, Rossow, LM, Thiebuaud, RS, and Bemben, MG. Methodological considerations for blood flow restricted resistance exercise. *J Trainology* 1: 14–22, 2012.
18. Abe T, Fujita S, Nakajima T, Sakamaki M, Ozaki H, Ogasawara R, Sugaya M, Kudo M, Kurano M, Yasuda T, Sato Y. Effects of low-intensity cycle training with restricted leg blood flow on thigh muscle volume and VO₂max in young men. *Journal of sports science & medicine*. 2010 Sep;9(3):452.
19. Fujita T, WF B, Kurita K, Sato Y, Abe T. Increased muscle volume and strength following six days of low-intensity resistance training with restricted muscle blood flow. *International Journal of KAATSU Training Research*. 2008;4(1):1-8.
20. Nielsen JL, Aagaard P, Bech RD, Nygaard T, Hvid LG, Wernbom M, Suetta C, Frandsen U. Proliferation of myogenic stem cells in human skeletal muscle in response to low-load resistance training with blood flow restriction. *The Journal of physiology*. 2012 Sep;590(17):4351-61.
21. Suchomel TJ, Wagle JP, Douglas J, Taber CB, Harden M, Haff GG, Stone MH. Implementing eccentric resistance training—part 1: a brief review of existing methods. *Journal of Functional Morphology and Kinesiology*. 2019 Jun;4(2):38.
22. Wilk M, Tufano JJ, Zajac A. The influence of movement tempo on acute neuromuscular, hormonal, and mechanical responses to resistance exercise—a mini review. *The Journal of Strength & Conditioning Research*. 2020 Aug 1;34(8):2369-83.
23. Levinger I, Goodman C, Hare DL, Jerums G, Toia D, Selig S. The reliability of the 1RM strength test for untrained middle-aged individuals. *Journal of science and medicine in sport*. 2009 Mar 1;12(2):310-6.
24. Fleck SJ, Kraemer WJ. Designing resistance training programs. Champaign, IL: Human Kinetics; 2004.
25. Kraemer WJ, Ratamess NA, Fry AC, et al. Strength training: development and evaluation of methodology. In: Maud PJ, Foster C, editors. *Physiological assessment of human fitness*. Champaign, IL: Human Kinetics; 2006. p. 119–50
26. Delavier F. Strength training anatomy. Human kinetics; 2010.
27. Nunes T, Coetzee B. The contribution of isokinetic strength parameters to the performance of cricket batsmen. *Isokinetics and exercise science*. 2007 Jan 1;15(3):233-44.
28. Beckham G, Lish S, Keebler L, Longaker C, Disney C, DeBeliso M, Adams KJ. The reliability of the seated medicine ball throw for distance. *Journal of Physical Activity Research*. 2019;4(2).
29. Harris, C., Wattles, A.P., DeBeliso, M., Sevene-Adams, P.G., Berning, J.M., and Adams, K.J. "The seated medicine ball throw as a test of upper body power in older adults," *Journal of Strength and Conditioning Research*, 25 (8). 2344-2348. 2011.
30. Beckham, G., Lish, S., Disney, C., Keebler, L., DeBeliso, M., Adams, K. J., "The Reliability of the Seated Medicine Ball Throw as Assessed with Accelerometer Instrumentation," *Journal of Physical Activity Research*, 7 (2). 108-113. 2019.
31. Manini TM, Clark BC. Blood flow restricted exercise and skeletal muscle health. *Exercise and sport sciences reviews*. 2009 Apr 1;37(2):78-85.





Revati Sunil Pagare et al.,

32. Reeves GV, Kraemer RR, Hollander DB, Clavier J, Thomas C, Francois M, Castracane VD. Comparison of hormone responses following light resistance exercise with partial vascular occlusion and moderately difficult resistance exercise without occlusion. *Journal of applied physiology*. 2006 Dec;101(6):1616-22.
33. Abe T, Hinata S, Koizumi K, Sato Y. Day-to-day change in muscle strength and MRI-measured skeletal muscle size during 7 days KAATSU resistance training: A case study. *International Journal of KAATSU Training Research*. 2005;1(2):71-6.
34. Fujita TW, WF B, Kurita K, Sato Y, Abe T. Increased muscle volume and strength following six days of low-intensity resistance training with restricted muscle blood flow. *International Journal of KAATSU Training Research*. 2008;4(1):1-8.
35. Chiu LZ, Fry AC, Schilling BK, Johnson EJ, Weiss LW. Neuromuscular fatigue and potentiation following two successive high intensity resistance exercise sessions. *European journal of applied physiology*. 2004 Aug;92:385-92.
36. Schlumberger A, Stec J, Schmidbleicher D. Single-vs. multiple-set strength training in women. *The Journal of Strength & Conditioning Research*. 2001 Aug 1;15(3):284-9.
37. SHOEPE, T.C., J.E. STELZER, D.P. GARNER, AND J.J. WIDRICK. Functional adaptability of muscle fibers to long-term resistance exercise. *Med. Sci. Sports Exerc*. 35:944–951. 2003.
38. Coyle EF, Feiring DC, Rotkis TC, Cote 3rd RW, Roby FB, Lee W, Wilmore JH. Specificity of power improvements through slow and fast isokinetic training. *Journal of applied physiology*. 1981 Dec 1;51(6):1437-42.
39. Brown LP, Niehues SL, Harrah A, Yavorsky P, Hirshman HP. Upper extremity range of motion and isokinetic strength of the internal and external shoulder rotators in major league baseball players. *The American journal of sports medicine*. 1988 Nov;16(6):577-85.
40. Heavens KR, Szivak TK, Hooper DR, Dunn-Lewis C, Comstock BA, Flanagan SD, Looney DP, Kupchak BR, Maresh CM, Volek JS, Kraemer WJ. The effects of high intensity short rest resistance exercise on muscle damage markers in men and women. *The Journal of Strength & Conditioning Research*. 2014 Apr 1;28(4):1041-9.
41. Fragala MS, Kraemer WJ, Denegar CR, Maresh CM, Mastro AM, Volek JS. Neuroendocrine-immune interactions and responses to exercise. *Sports Medicine*. 2011 Aug;41:621-39.
42. Kraemer WJ, Ratamess NA. Hormonal responses and adaptations to resistance exercise and training. *Sports medicine*. 2005 Apr;35:339-61.
43. Spiering BA, Kraemer WJ, Vingren JL, Ratamess NA, Anderson JM, Armstrong LE, Nindl BC, Volek JS, Häkkinen K, Maresh CM. Elevated endogenous testosterone concentrations potentiate muscle androgen receptor responses to resistance exercise. *The Journal of steroid biochemistry and molecular biology*. 2009 Apr 1;114(3-5):195-9.
44. Krzysztofik M, Wilk M, Filip A, Zmijewski P, Zajac A, Tufano JJ. Can post-activation performance enhancement (PAPE) improve resistance training volume during the bench press exercise?. *International Journal of Environmental Research and Public Health*. 2020 Apr;17(7):2554.
45. Tillin NA, Bishop D. Factors modulating post-activation potentiation and its effect on performance of subsequent explosive activities. *Sports medicine*. 2009 Feb;39:147-66.

Table 1: -Distribution of the participants according to age

AGE	TOTAL	PERCENTAGE
18-20	25	46.2962%
21-23	19	35.1851%
24-25	10	18.00%





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Within Group Analysis

Table: -2 Comparison of pre and post data for 1RM Bench press

		Mean	SD	Z-value	P-value
Group A	Pre	24	5.96	-378	0.002
	Post	39.96	12.522		
Group B	Pre	24.74	7.60	-378.0	0.0001
	Post	39.07	10.32		

Table: -3 Comparison of pre and post data for Medicine ball chest pass in cross leg sitting

		Mean	SD	Z-value	P-value
Group A	Pre	205.18	50.94	-378.0	0.001
	Post	317.03	69.77		
Group B	Pre	204.4	53.44	-378.0	0.0001
	Post	286.29	53.21		

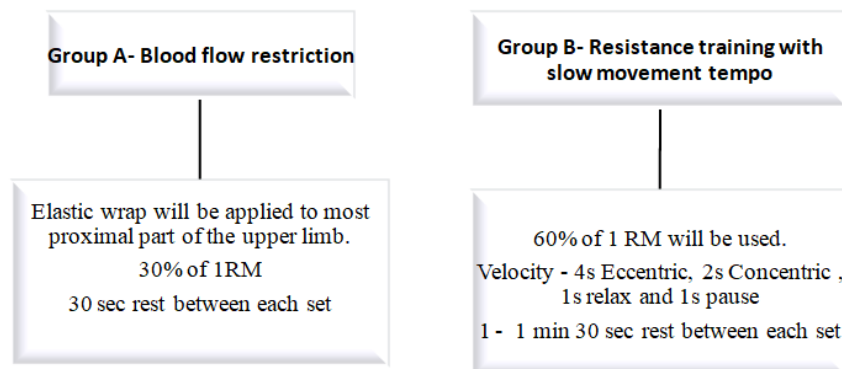
BETWEEN GROUP ANALYSIS

Table -4 Comparison of mean difference of 1RM for both groups

	Mean	SD	Z – Value	P– value
Group A	15.96	9.35	-206.50	0.761
Group B	14.33	5.9		

Table -5 Comparison of mean difference of Medicine ball chest pass in cross leg sitting for both groups

	Mean	SD	Z – Value	P– value
Group A	111.85	56.16	-70.50	0.615
Group B	81.85	30.88		



Exercise	Sets	Repetition
Single arm dumbbell row	3	10
Dumbbell hammer curls	3	10
Tricepdumbbell extension	3	10
Upright rows	3	10
Bicep curls	3	10
Bench press	3	10

Fig.1. Training Protocol





A Comparative Study of Fermented and Non-Fermented Bamboo Shoot and their Applications in Nutraceutical and Pharmaceuticals

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ABSTRACT

The utilization of bamboo shoots as a traditional food source across various cultures has offered numerous nutritional and sensory benefits. Fermentation of bamboo shoots can modify their chemical composition and improve their bioactivity by introducing beneficial microorganisms. Bioactive compounds, including phenolics, flavonoids, organic acids, and enzymes are generated through the fermentation process of bamboo shoots. The compounds possess diverse pharmacological properties, encompassing antioxidant, antimicrobial, anti-inflammatory and anti-cancer activities. Research has indicated that fermented bamboo shoots exhibit enhanced nutritional characteristics, including higher dietary fibre content and improved bioavailability of essential nutrients. Fermented bamboo shoot extracts and their bioactive compounds have potential applications in pharmaceutical formulations and





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traditional medicine. Further investigation is required to determine the specific bioactive compounds, their modes of operation, and the optimal fermentation conditions for enhancing the pharmacological capabilities of fermented bamboo shoots. In addition, it is necessary to conduct safety evaluations and clinical trials to verify the effectiveness and safety of fermented bamboo shoot-based products intended for human consumption.

Keywords: Fermented bamboo shoot, Active biomass, Nutraceuticals, Pharmaceuticals, Bioactive Compounds, Functional foods, Medicinal properties.

INTRODUCTION

Bamboo shoots have long been recognized as a valuable dietary component in Asian cuisines, prized for their unique flavor and nutritional properties. As per reports 1250 species of bamboo is belonging to 75 genera from where 125 species of bamboo shoots are edible. One of the best-suited most widely used forest trees is the bamboo which belongs to the Poaceae family. It also goes by the name "green gold" in India. Compared to other conventional medical plants, it is one of the highly appreciated medicinal herbs. Bamboo has a long history of being connected to people[1]. The young shoots of bamboos which are mostly used for industrial purposes, are also used as food and can be eaten fresh, fermented, or canned. The young shoots are not only tasty but also packed with nutrients including proteins, carbohydrate and fats. They also include minerals and little sugar. They also have a lot of fibre and phytosterols, which are considered nutraceuticals or natural medications that are gaining popularity with health professionals[2]. Fermentation is commonly defined as a process wherein a product is generated through the cultivation of a mass of microorganisms. It has been a longstanding practice in human consumption of food. Biotechnology is employed to both create and preserve fermented foods, which hold a significant place in our daily dietary habits. Enzymes or bacteria are utilized during fermentation to induce essential biochemical changes and alterations in the food's composition. These fermented foods play a crucial role in our diets, and biotechnology serves as a tool for their production and preservation over extended periods [3]. Fermented bamboo shoots are traditional food that is popular in various Asian cuisines, particularly in countries like India, Nepal, China and Thailand.

Bamboo shoots are the young and tender sprouts that emerge from the ground and grow on bamboo plants. They have a crisp texture and a mild, slightly sweet flavor. The process of fermenting bamboo shoots involves preserving them in a brine solution or by burying them underground. Fermentation helps to enhance the flavor, extend the shelf life and develop unique characteristics in the bamboo shoots[4]. The fermentation process of bamboo shoots varies depending on regional and culinary traditions. Beneficial bacteria and yeast naturally present on the shoots initiate fermentation, breaking down complex carbohydrates and proteins into simpler compounds, imparting a distinctive taste and aroma to fermented bamboo shoots. Widely used in soups, stir-fries, curries, pickles, and salads, fermented bamboo shoots add a tangy, slightly sour flavor, enhancing the overall appeal of dishes[5]. Before cooking, the shoots are often rinsed or soaked to mitigate any excess saltiness or bitterness that may develop during fermentation[3]. Khorisa is a traditional fermented bamboo shoot product from Assam, India. It is a staple in the diets of both rural and urban people and it is frequently used as the main component in dishes like meat and fish preparations, pickles and other foods[6]. Many bamboo shoots traded internationally are now canned or preserved but due to growing consumer desire for whole foods, it is anticipated that fresh shoots will soon account for a large portion of commerce. This study aims to compare fermented and non-fermented bamboo shoots, examining their nutritional content, bioactive compounds, and pharmacological effects, and discussing their prospective roles in promoting human health[7].





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FERMENTATION PROCESS TRADITIONAL OR CONVENTIONAL METHODS

Fermentation is an enzyme-catalyzed metabolic process in which organisms convert starch or sugar to alcohol or an acid by releasing energy anaerobically. The scientific study of fermentation is called as "Zymology". There are mainly two types of fermentation process like homo fermentation and hetero fermentation process. Fermentation process consist many advantages such as it suitable for all kind of environment and also used in various industrial purposes. Bamboo shoot fermentation is a traditional method practiced mainly in several Fermentation villages throughout the North-Eastern area. Laboratory validation of fermentation bamboo shoot can shows better comprehend to it. With the addition of inoculums, the shoots were fermented for 30 days. Fermented bamboo shoot can last more than one year if it stores properly. Fermented bamboo shoots are low in fat and rich in protein, carbohydrates, fibers and minerals[8].

FERMENTATION METHOD

METHOD 1

Bamboo shoot was collected and outer sheath was removed. For fermentation the white component was cleaned and grated. The traditional method was applied for fermentation both in the field and in the laboratory. To expedite the process, 100 grams of shoots were combined with 10% inoculum (traditionally fermented 2-year-old bamboo shoot). The shoots were sealed in glass jar and fermented in triplicates at room temperature (29.4-32.4 °C) and relative humidity (52-72 %). The sample was tested at intervals of 0, 6, 12 and 24 hours on the first day. Following that, tests were conducted on days 2, 5, 8, 13, 18, 24 and 30 to assess changes in pH, cyanogenic toxicity and treatable acidity. The final fermented bamboo shoot product was further analyzed for the proximate composition, minerals and antioxidant capacity[9].

METHOD 2

In this procedure, the glass bottle is filled with the cut bamboo shoots and water is then poured until the bamboo shoots are completely immersed. The bottle is then tightly capped and stored in a corner of the room or above the home's cooking area for fermentation. Fermentation in bottles offers better keeping quality for fermented bamboo shoots compared to fermentation within bamboo cylinders. When it comes to bamboo cylinders the product must be used within one or two months, whereas shoots in a bottle can be stored for up to a year. Urban residents are more likely to ferment bamboo shoots in glass bottles than rural residents and farmers who prefer to ferment bamboo shoots within bamboo cylinders[10].

Nutraceutical values of fermented bamboo shoots

Any product derived from food sources that offers additional health benefits beyond the basic nutritional content present in foods is referred to as a nutraceutical under the wide umbrella term. Since ancient time people used bamboo shoot to prevent various kind of disease. Bamboo shoot can be used as fermentation and also in raw form. But modern research and advance technology had proved that fermented bamboo shoot have more nutraceutical value than raw one because fermented shoot consist microorganism that can work better against several types of disease[17]. Bamboo shoots are indeed utilized as food resources. Various edible species and exotic food products such as fermented shoots and pickles are made from bamboo shoots, which can be helpful in preventing various diseases. Bamboo shoots are rich in phytosterols and fiber, making them potentially valuable as "nutraceuticals". Phytosterols, as suggested, possess cholesterol-lowering properties. For individuals such as children and premenopausal women, as well as those who are pregnant or breastfeeding, there is a heightened need for iron. Bamboo shoots offer a noteworthy source of iron compared to many other commonly consumed vegetables, fulfilling this nutritional requirement effectively. Bamboo shoot recipes such as bamboo beer and bamboo biscuits are consumed globally. Scientist have proof that various preparation of bamboo shoot species can have different kind of nutraceutical values or health benefits[18,19]. Fermented bamboo shoots present a plethora of nutraceutical benefits that contribute to overall health and well-being. One of the key advantages lies in the process of fermentation itself, which enhances the nutrient profile of bamboo shoots. Through fermentation, the bioavailability of essential





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nutrients such as vitamins, minerals, and amino acids is significantly increased, making these nutrients more accessible and readily absorbed by the body. This enrichment of nutrients adds to the nutritional value of fermented bamboo shoots, providing a more wholesome and nourishing food source[20,21]. They are also endowed for having essential amino acids; selenium, a potent antioxidant and potassium, a healthy heart mineral.

PHARMACEUTICAL VALUES OF MICROORGANISM CONTENT BAMBOO SHOOT

Microbes found in fermented bamboo shoots significantly contribute to their medicinal properties. These microbes act as probiotics, aiding digestion, regulating gut flora and bolstering the immune system. Furthermore, fermentation enriches the nutritional content of bamboo shoots by increasing the availability of essential nutrients such as vitamins, minerals, and amino acids. The pharmaceutical values of fermented bamboo shoots reportedly encompass properties such as anti-cancer effects, cardiovascular disease prevention, weight loss facilitation, improved digestion, antibacterial attributes and antioxidant properties[22,23]. Bioactive compounds of fermented bamboo shoots also have different health benefits. The main function of bioactive compound is to promote good health. Bioactive compounds like phenols, phytosterols and dietary fibres etc can promote health and can cure chronic and degenerative disease[24]. Phenolic compounds of raw as well as fermented bamboo shoot also have multiple biological functions such as it has properties like antioxidant, antimicrobial, anti-aging, antifatigue also can treat cardiovascular diseases[25]. Dietary fibres and phytosterols improve lipid profiles and gastrointestinal function by lowering total serum cholesterol and low-density lipoprotein cholesterol levels[19]. Certain microorganisms present in fermented bamboo shoots can produce antimicrobial compounds. These compounds may inhibit the growth of harmful bacteria, fungi or other pathogens[26]. For example, bacteriocins produced by lactic acid bacteria have been found to possess antimicrobial properties and can help prevent food spoilage and protect against foodborne pathogens. This can improve the overall nutritional profile of bamboo shoots and potentially enhance their therapeutic benefits[27].

COMPARISON OF PHYTOCONSTITUENTS OF FERMENTED AND NON-FERMENTED BAMBOO SHOOT

Phenol

Non-fermented bamboo shoots naturally contain phenolic compounds. Phenols are a class of organic compounds that are widely distributed in plants and can have antioxidant and antimicrobial properties[28]. Bamboo shoots whether fermented or not contain various phenolic compounds, including flavonoids and phenolic acids. Phenolic compounds in bamboo shoots are believed to contribute to their potential health benefits. These compounds possess antioxidant properties, which help protect the body's cells from damage caused by free radicals[29]. Antioxidants are known to have potential anti-inflammatory and anti-cancer effects. Non-fermented bamboo shoots can be consumed in a variety of ways including stir-fries, salads, and soups. When cooked, the phenolic compounds in bamboo shoots are not significantly altered and their potential health benefits can still be retained. It is worth noting that the exact composition and concentration of phenolic compounds in bamboo shoots can vary depending on factors such as the bamboo species, maturity of the shoots and growing conditions. Additionally, cooking methods and processing techniques may also influence the final phenolic content of bamboo shoots[30]. Incorporating a variety of fruits, vegetables and other plant-based foods is key to obtaining a wide range of beneficial compounds for optimal health. The higher the quantity of total phenolic compounds, the greater the rise in antioxidant activity. Some of the studies discovered differences in the phenolic compounds found in bamboo shoots of *Dendrocalamus asper*, *Dendrocalamus sstrictus* and *Bambusa tulda* at various harvesting periods[31]. The gallic acid content increased in *Dendrocalamus asper*, while the concentration of caffeic acid increased in all bamboo species as shoot age progressed.

Phytosterols

Phytosterols are a type of plant molecule with a structure like cholesterol that has been connected to several health benefits. They can be found in plants such as bamboo shoots. The amount of phytosterols in bamboo shoots may differ depending on the processing methods used such as fermentation[32]. Fermentation has the potential to alter





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the composition and nutritional profile bamboo shoots. Several parameters should be addressed when comparing the phytosterol concentration of fermented and non-fermented bamboo shoots[33].

Total Phytosterol Content

Fermentation may have an effect on the overall phytosterol content of bamboo shoots. According to several studies, fermentation can increase the level of phytosterols in specific foods. However, there has been minimal research comparing fermented and unfermented bamboo shoots and the results may change depending on the fermentation method used[34,35].

Composition of Phytosterols

Phytosterols comprise various compounds, such as beta-sitosterol, campesterol and stigmasterol. The composition of phytosterols in bamboo shoots may be influenced by fermentation. Some studies have reported changes in the relative proportions of different phytosterols during fermentation processes. Again, more research is needed to determine the specific effects on bamboo shoots[35,36,37].

Bioavailability

While phytosterol quantity is important, so is phytosterol bioavailability. Fermentation may increase phytosterol bioavailability by dissolving plant cell walls and making them more accessible to the human digestive system. This higher bioavailability has the potential to enhance phytosterol health benefits[38,39,40]. It is important to note that the research on the phytosterol content of fermented and non-fermented bamboo shoots is limited. Fermentation's exact effects on phytosterols in bamboo shoots may vary based on the fermentation procedure, length and other factors. Further research on the phytosterol level and composition of fermented and non-fermented bamboo shoots is required to establish a more exact comparison[41].

Lignin

Lignin is a complex chemical present in plant cell walls such as bamboo shoots. It gives the plant structural strength and stiffness. Various factors including processing methods such as fermentation, can impact the lignin concentration in bamboo shoots. When comparing the lignin content in fermented and non-fermented bamboo shoots, the following points should be considered: Lignin Degradation-Fermentation processes, particularly those involving microorganisms like bacteria or yeast, can induce lignin breakdown or modification. These bacteria produce ligninolytic enzymes, such as lignin peroxidase and laccase, which can degrade lignin into smaller components. Consequently, fermented bamboo shoots may exhibit lower lignin concentrations compared to non-fermented bamboo shoots[42].

Structural Changes

Fermentation can produce structural changes in plant tissues, such as cell wall disintegration. Lignin is an important component of cell walls, and the fermentation process has the ability to disturb its structure. This can have an effect on the quantity and properties of lignin in fermented bamboo shoots vs non-fermented ones[43].

Analysis Methods

Various analytical procedures such as the Klason lignin method, acid detergent lignin method, or spectroscopic techniques such as Fourier-transform infrared spectroscopy (FTIR) are used to determine lignin concentration. Because of their specificity, precision and capacity to quantify lignin in different forms (e.g.: soluble or insoluble lignin), different techniques may produce diverse findings. As a result, the technique of analysis used can affect the comparison of lignin levels in fermented and unfermented bamboo shoots[44]. It is vital to note that research on the lignin concentration of fermented and unfermented bamboo shoots is limited. Fermentation's impact on lignin in bamboo shoots might vary based on the fermentation procedure, time, microbial strains involved and other variables. More research is needed to have a better understanding of how fermentation affects the lignin concentration and properties of bamboo shoots[45].





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Cellulose

Cellulose is a fundamental component of plant cell walls that is abundant in bamboo shoots. The following criteria should be considered when comparing the cellulose content of fermented and non-fermented bamboo shoots.

Cellulose Preservation

The fermentation processes, especially those involving microbes have the potential to impact cellulose preservation in bamboo shoots. Bacterial enzymatic activity may break down cellulose into smaller sugars such as glucose, which the bacteria utilize as a carbon source. This could lead to a reduction in cellulose content in fermented bamboo shoots compared to non-fermented bamboo shoots[46].

Structural Changes

The principle of fermentation to structural changes in plant tissues, including the breakdown of cell walls. Cellulose is a main component of the plant cell wall and the fermentation process can potentially disrupt the cellulose structure. This may affect the quantification and characteristics of cellulose in fermented bamboo shoots compared to non-fermented ones[47].

Analysis Methods

Various analytical procedures such as the acid detergent fibre method, the Van Soest method or enzymatic tests are used to determine cellulose concentration. Because of their specificity, precision and capacity to quantify cellulose in different forms (e.g., crystalline or amorphous cellulose), different techniques may produce diverse findings. The comparison of cellulose concentration in fermented and non-fermented bamboo shoots might be influenced by the technique of analysis used[45]. It is important to note that research specifically focusing on the cellulose content in fermented and non-fermented bamboo shoots is limited. Fermentation's effects on cellulose in bamboo shoots vary based on the fermentation procedure, time, microbial strains involved and other variables. More research is needed to have a better understanding of how fermentation affects the cellulose content and properties of bamboo shoots[48].

Taxiphyllin

Taxiphyllin is a cyanogenic glycoside found in bamboo shoots and other plants. Cyanogenic glycosides are substances that when hydrolyzed by enzymes, emit deadly hydrogen cyanide[49]. The following criteria should be considered when comparing the taxiphyllin concentration of fermented and unfermented bamboo shoots:

Cyanogenesis Potential

Cyanogenic glycosides including taxiphyllin are typically present in plants as a defense mechanism against herbivores and pathogens. However, the levels of taxiphyllin can vary among different plant parts and species[50]. It is important to note that taxiphyllin content can also be influenced by genetic factors, environmental conditions and plant maturity[49].

Fermentation Effects

Fermentation activities, particularly those involving microbes may have an effect on the taxiphyllin concentration of bamboo shoots. According to some research, various fermentation procedures can lower the quantities of cyanogenic glycosides in bamboo shoots. Microorganisms engaged in fermentation may produce enzymes such α -glucosidases that hydrolyze taxiphyllin, resulting in lower quantities of this molecule. However, depending on the fermentation conditions and microbial strains used, the level of taxiphyllin reduction might vary[51].

Cyanide Release

Fermentation activities, particularly those involving microbes, have the ability to affect the taxiphyllin content of bamboo shoots. According to certain research, some fermentation procedures can lower the quantities of cyanogenic glycosides in foods such as bamboo shoots. Microorganisms engaged in fermentation may have enzymes, such as α -glucosidases, that may hydrolyze taxiphyllin, resulting in lower quantities of this molecule[52,53]. However, the





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quantity of taxiphyllin reduction during fermentation might vary depending on the fermentation circumstances and microbial strains involved[54,55,56]. The effects of fermentation on taxiphyllin levels can vary depending on the fermentation process, duration, microbial strains involved and other factors. Further studies are needed to provide a more comprehensive understanding of how fermentation impacts the taxiphyllin content in bamboo shoots and ensure the safety of fermented bamboo shoot products[57].

Dietary Fibre

Dietary fibres have a range of health advantages, including the ability to reduce blood pressure, hypertension and obesity as well as to shield the body from dangerous carcinogens and cardiovascular disorders[58]. Consuming a diet high in fibre reduces the levels of bad cholesterol (low density lipoprotein and very low-density lipoprotein) in the blood, lowers insulin requirements, maintains the integrity of the digestive system, and enhances laxative properties[59]. In young, healthy women, the use of bamboo shoots regularly improves lipid profiles and bowel movements[60]. Fermentation processes can have an impact on the dietary fiber content of bamboo shoots. Dietary fiber refers to the indigestible carbohydrates present in plants that provide various health benefits. When comparing the dietary fiber content in fermented and non-fermented bamboo shoots, the following factors should be considered.

Total Dietary Fibre

The total dietary fibre content of bamboo shoots might alter due to fermentation. Some research has found that the dietary fibre content of various plant-based meals rises during fermentation. These increases may be attributable to fermenting bacteria producing extra soluble fibre components such as beta-glucans and oligosaccharides[61].

Soluble Fiber

Fermentation has been shown to increase the formation of soluble fibre in bamboo shoots. Soluble fibre is well-known for its capacity to dissolve in water and produce a gel-like material in the digestive tract, which helps improve digestive health. Microorganisms may ferment complex carbohydrates and create soluble fibre components like pectins and gums[62].

Insoluble fibre

Such as cellulose and hemicellulose, bulks up the stool and promotes regular bowel motions. While fermentation may induce some cellulose and hemicellulose breakdown, it is predicted that some of the insoluble fibre content will survive in fermented bamboo shoots. However, depending on the fermentation technique and time, the level of breakdown and overall influence on the insoluble fibre concentration may vary[63].

Prebiotic Fiber

Prebiotic fibres are kinds of dietary fibre that serve as a food supply for good gut bacteria. Fermentation has the potential to improve prebiotic fibre content in bamboo shoots, fostering a healthy gut flora. During the digestion of dietary fibre, fermenting bacteria can create short-chain fatty acids (SCFAs) which can bring extra advantages to the digestive system[64]. It is important to note that research specifically focusing on the dietary fiber content of fermented Bamboo shoots is limited. The effects of fermentation on dietary fiber content can vary depending on the fermentation process, microbial strains involved and other factors. Further studies are needed to provide a more comprehensive understanding of how fermentation impacts the dietary fiber content and composition of bamboo shoots[65].

APPLICATION OF FERMENTED AND NON-FERMENTED BAMBOO SHOOTS IN PHARMACEUTICALS

Bamboo shoots (both fermented and non-fermented), have a variety of therapeutic purposes. Here are some examples of possible applications:





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Traditional Medicine

Bamboo shoots have been employed for medicinal purposes in traditional medicine systems. For their potential health advantages, both fermented and non-fermented bamboo shoots can be used into traditional medical treatments such as herbal formulations or nutritional supplements[66].

Antioxidant Activity

Bamboo shoots, especially fermented ones, contain bioactive chemicals that are antioxidants. These molecules, such as phenolics and flavonoids, can scavenge free radicals and protect against illnesses caused by oxidative stress. Bamboo shoot extracts, whether fermented or unfermented can be used as natural antioxidants in medicinal compositions[67].

Anti-inflammatory Effects

Bamboo shoots have been reported to possess anti-inflammatory properties. Active compounds present in bamboo shoots, including flavonoids and other phytochemicals, can inhibit inflammatory pathways and help alleviate inflammation-associated conditions. Pharmaceutical products containing extracts from fermented or non-fermented bamboo shoots may have potential as anti-inflammatory agents[68].

Antibacterial Agents

Bamboo shoots, particularly fermented bamboo shoots can contain antibacterial chemicals generated by microorganisms during fermentation. These chemicals have antibacterial, antifungal and anti-pathogen action. Antimicrobial activity of extracts or isolated components from fermented bamboo shoots can be investigated and exploited in the creation of pharmaceutical formulations for treating microbial illnesses[69].

Nutritional Supplementation

Bamboo shoots, whether fermented or non-fermented are rich in dietary fiber, vitamins and minerals. These nutritional components can be utilized in pharmaceutical products as dietary supplements to address specific nutrient deficiencies or support overall health and wellness[70].

Anti-Cancer Activity

Mammalian cell transformation methods are particularly helpful among several short-term assessment techniques for the detection of environmental carcinogens/mutagens since their test endpoint is neoplastic conversion of target cells[69]. Traditional Japanese medicine uses kumaizasa bamboo leaf extracts as an anti-inflammatory. The anticancer activity and immunopotentiating efficiency of bamboo (*Sasa senanensis*) leaf extracts prepared under 'vigorous conditions' were investigated in research on immuno stimulation-mediated anti-tumor activity. The extracts activated both macrophages and natural killer cells indicating that it may be the major immunopotentiating component in cancer prevention[71].

Anti-Diabetic Activity

Type 2 diabetes is caused by reduced pancreatic insulin production and insulin resistance in multiple tissues such as the liver, muscle and adipose, resulting in impaired glucose uptake. The *Sasa borealis* extract have the ability to reduced plasma glucose levels, showing that this extract has anti-diabetic properties[72]. The leaves of *Sasa borealis*, a bamboo species have been shown to have anti-hyperglycemic properties. However, the mechanism of its anti-diabetic action was not entirely understood. The anti-diabetic action of *Sasa borealis* extract was also investigated by activation of the AMP-activated protein kinase[73]. It should be noted that more research and development is needed to investigate the particular chemicals, modes of action and safety profiles of fermented and non-fermented bamboo shoots for pharmaceutical uses. Additionally, regulatory considerations and clinical studies are necessary to ensure the efficacy and safety of bamboo shoot-based pharmaceutical products[74].





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APPLICATION OF FERMENTED AND NON-FERMENTED BAMBOO SHOOTS IN NEUTRACEUTICALS

Bamboo shoots, both fermented and non-fermented have a variety of applications in the nutraceutical business, which focuses on the utilization of natural ingredients for health and wellness. Here are some possible applications for fermented and unfermented bamboo shoots in nutraceutical:

Dietary Supplements

Bamboo shoots, whether fermented or non-fermented, are rich in essential nutrients, including dietary fiber, vitamins (such as vitamin C and vitamin E), minerals (such as potassium and manganese) and antioxidants. Nutraceutical products in the form of capsules, tablets or powders can be developed using bamboo shoot extracts or powdered forms to provide a concentrated source of these nutrients [89].

Antioxidant Support

Bamboo shoots contain bioactive substances with antioxidant characteristics, such as phenolics and flavonoids. These substances can aid in the neutralisation of damaging free radicals and protect the organism from oxidative stress. Antioxidant support can be provided by nutraceutical formulations including fermented or unfermented bamboo stalk extracts promoting general health and well-being[90].

Digestive Health

Bamboo shoots, particularly fermented ones, may contain probiotic microbes that support digestive health. Probiotics are helpful bacteria that help the gut microbiota balance and promote appropriate digestion. Nutraceuticals containing fermented bamboo shoot extracts or probiotic strains can assist improve digestive health and nutrient absorption[91].

Weight Management

Bamboo shoots are low in calories and high in dietary fibre, making them an ideal ingredient in weight-management nutraceuticals. Bamboo shoot's high fibre content helps enhance feelings of fullness, reduce hunger and improve good digestion. Nutraceutical formulations based on bamboo shoot extracts or powdered forms can be created to aid in weight loss programs[92].

Bone Health

Bamboo shoots contain minerals like calcium, magnesium, and potassium, which are essential for maintaining healthy bones. Nutraceutical products enriched with bamboo shoot extracts can provide a natural source of these minerals to support bone health and prevent conditions like osteoporosis[93].

Cardiovascular Health

Bamboo shoots have been reported to possess cardiovascular benefits. They are low in cholesterol and sodium while being rich in potassium, which can help regulate blood pressure. Nutraceutical formulations containing bamboo shoot extracts may contribute to cardiovascular health by promoting healthy blood pressure levels and supporting overall heart function[94].

Anti-Inflammatory Support

Bamboo shoots, particularly fermented ones, may contain anti-inflammatory chemicals. These substances can aid in the reduction of inflammation in the body, which is linked to a variety of chronic illnesses. Natural anti-inflammatory assistance may be provided by nutraceutical products containing fermented or unfermented bamboo shoot extracts[95]. It is critical to note that the specific components and amounts of these compounds in fermented and non-fermented bamboo shoots might differ based on factors such as bamboo species, growing circumstances and processing processes. To optimize the composition and dose of bamboo shoot-based nutraceutical products for particular health advantages, more study and product development are required.





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CONCLUSION

The comparison highlights notable distinctions between fermented and non-fermented bamboo shoots concerning their nutritional composition and bioactive elements. Fermentation gives rise to advantageous metabolites such as organic acids, phenolic compounds, and enzymes, which augment their bioactivity and potential health advantages. Fermented bamboo shoots demonstrate heightened antioxidant, anti-inflammatory, antimicrobial, and anticancer attributes in contrast to non-fermented ones. These observations imply that fermented bamboo shoots present an opportunity as functional components in creating dietary supplements, functional foods, and pharmaceutical formulations intended for improving human health and disease prevention. The research identifies numerous potential avenues for utilizing fermented bamboo shoots in the fields of nutraceuticals and pharmaceuticals. It suggests the need for further exploration to understand the mechanisms behind the pharmacological effects of fermented bamboo shoots and to refine fermentation methods to boost their bioactivity. Additionally, clinical trials are essential to confirm the health benefits of fermented bamboo shoots and assess their effectiveness in preventing and treating different diseases. Furthermore, efforts should concentrate on devising novel formulations and delivery methods that incorporate fermented bamboo shoots to maximize their therapeutic efficacy and guarantee their safe and efficient utilization in healthcare contexts.

REFERENCES

1. Das AJ, Deka SC. Fermented foods and beverages of the North-East India. *International Food Research Journal*. 2012 Apr 1;19(2):377.
2. Tamang JP, Thapa N, Bhalla TC, Savitri. Ethnic fermented foods and beverages of India. *Ethnic fermented foods and alcoholic beverages of Asia*. 2016:17-72.
3. Rawat K, Kumari A, Kumar S, Kumar R, Gehlot R. Traditional fermented products of India. *Int J Curr Microbiol App Sci*. 2018;7(4):1873-83.
4. Tamang JP, Tamang N, Thapa S, Dewan S, Tamang B, Yonzan H, Rai AK, Chettri R, Chakrabarty J, Kharel N. Microorganisms and nutritional value of ethnic fermented foods and alcoholic beverages of North East India.
5. Narzary Y, Brahma J, Brahma C, Das S. A study on indigenous fermented foods and beverages of Kokrajhar, Assam, India. *Journal of Ethnic foods*. 2016 Dec 1;3(4):284-91.
6. Tamang JP, Sarkar PK, Hesseltine CW. Traditional fermented foods and beverages of Darjeeling and Sikkim—a review. *Journal of the Science of Food and Agriculture*. 1988;44(4):375-85.
7. Jeyaram K, Singh TA, Romi W, Devi AR, Singh WM. Traditional fermented foods of Manipur.
8. Singhal P, Satya S, Naik SN. Fermented bamboo shoots: A complete nutritional, anti-nutritional and antioxidant profile of the sustainable and functional food to food security. *Food Chemistry: Molecular Sciences*. 2021 Dec 30;3:100041.
9. Agrahar-Murugkar D, Subbulakshmi G. Preparation techniques and nutritive value of fermented foods from the Khasi tribes of Meghalaya. *Ecology of food and nutrition*. 2006 Jan 1;45(1):27-38.
10. Nehal N. Knowledge of traditional fermented food products harbored by the tribal folks of the Indian Himalayan belt. *Int J Agric Food Sci Technol*. 2013;4(5):401-14.
11. Chongtham N, Bisht MS, Haorongbam S. Nutritional properties of bamboo shoots: potential and prospects for utilization as a health food. *Comprehensive Reviews in Food Science and Food Safety*. 2011 May;10(3):153-68.
12. Singhal P, Satya S, Naik SN. Fermented bamboo shoots: A complete nutritional, anti-nutritional and antioxidant profile of the sustainable and functional food to food security. *Food Chemistry: Molecular Sciences*. 2021 Dec 30;3:100041.



**Izaz Hussain et al.,**

13. Nongdam P, Tikendra L. The nutritional facts of bamboo shoots and their usage as important traditional foods of northeast India. International scholarly research notices. 2014;2014.
14. Yi J, Li M, Yang M, Cai S, Zhao T, Cao J, Cheng G. Characterisation and in vitro cytotoxicity of toxic and degradation compounds in bamboo shoots (*Dendrocalamus Sinicus*) during traditional fermentation. International Journal of Food Science & Technology. 2021 Feb;56(2):974-87.
15. Sharma N, Barooah M. Microbiology of khorisa, its proximate composition and probiotic potential of lactic acid bacteria present in Khorisa, a traditional fermented Bamboo shoot product of Assam.
16. Choudhury D, Sahu JK, Sharma GD. Bamboo shoot: microbiology, biochemistry and technology of fermentation-a review.
17. Bajwa HK, Santosh O, Chongtham N. Bioactive compounds in bamboo shoot. Bioactive Compounds in Underutilized Vegetables and Legumes. 2020:1-22.
18. Singhal P, Bal LM, Satya S, Sudhakar P, Naik SN. Bamboo shoots: a novel source of nutrition and medicine. Critical reviews in food science and nutrition. 2013 Jan 1;53(5):517-34.
19. Wang Y, Chen J, Wang D, Ye F, He Y, Hu Z, Zhao G. A systematic review on the composition, storage, processing of bamboo shoots: Focusing the nutritional and functional benefits. Journal of Functional Foods. 2020 Aug 1;71:104015.
20. Emamverdian A, Ding Y, Ranaei F, Ahmad Z. Application of bamboo plants in nine aspects. The Scientific World Journal. 2020 Sep 30;2020.
21. Nirmala C, Bisht MS, Laishram M. Bioactive compounds in bamboo shoots: health benefits and prospects for developing functional foods. International Journal of Food Science & Technology. 2014 Jun;49(6):1425-31.
22. Luo C, Xu X, Wei X, Feng W, Huang H, Liu H, Xu R, Lin J, Han L, Zhang D. Natural medicines for the treatment of fatigue: Bioactive components, pharmacology, and mechanisms. Pharmacological Research. 2019 Oct 1;148:104409.
23. Wang Y, Chen J, Wang D, Ye F, He Y, Hu Z, Zhao G. A systematic review on the composition, storage, processing of bamboo shoots: Focusing the nutritional and functional benefits. Journal of Functional Foods. 2020 Aug 1;71:104015.
24. Wu W, Hu J, Gao H, Chen H, Fang X, Mu H, Han Y, Liu R. The potential cholesterol-lowering and prebiotic effects of bamboo shoot dietary fibers and their structural characteristics. Food chemistry. 2020 Dec 1;332:127372.
25. Li X, Guo J, Ji K, Zhang P. Bamboo shoot fiber prevents obesity in mice by modulating the gut microbiota. Scientific reports. 2016 Sep 7;6(1):32953.
26. Chongtham N, Bisht MS, Santosh O, Bajwa HK, Indira A. Mineral elements in bamboo shoots and potential role in food fortification. Journal of Food Composition and Analysis. 2021 Jan 1;95:103662
27. Arroyo BJ, Santos AP, de Melo ED, Campos A, Lins L, Boyano-Orozco LC. Bioactive compounds and their potential use as ingredients for food and its application in food packaging. In Bioactive compounds 2019 Jan 1 (pp. 143-156). Woodhead Publishing.
28. Rotelli AE, Guardia T, Juárez AO, De la Rocha NE, Pelzer LE. Comparative study of flavonoids in experimental models of inflammation. Pharmacological research. 2003 Dec 1;48(6):601-6.
29. Rotelli AE, Guardia T, Juárez AO, De la Rocha NE, Pelzer LE. Comparative study of flavonoids in experimental models of inflammation. Pharmacological research. 2003 Dec 1;48(6):601-6.



**Izaz Hussain et al.,**

30. Morikawa K, Nonaka M, Narahara M, Torii I, Kawaguchi K, Yoshikawa T, Kumazawa Y, Morikawa S. Inhibitory effect of quercetin on carrageenan-induced inflammation in rats. *Life Sciences*. 2003 Dec 26;74(6):709-21.
31. Lee SJ, Son KH, Chang HW, Do JC, Jung KY, Kang SS, Kim HP. Antiinflammatory activity of naturally occurring flavone and flavonol glycosides. *Archives of Pharmacal Research*. 1993 Mar;16:25-8.
32. Shukla R, Pandey V, Vadnere GP, Lodhi S. Role of flavonoids in management of inflammatory disorders. In *Bioactive food as dietary interventions for arthritis and related inflammatory diseases 2019* Jan 1 (pp. 293-322). Academic Press.
33. Srivastava RC. Bamboo, new raw material for phytosterols. *Current Science*. 1990;59(24):1333-4.
34. Miettinen, Gylling. Non-nutritive bioactive constituents of plants: phytosterols. *International journal for vitamin and nutrition research*. 2003 Mar 1;73(2):127-34.
35. Kritchevsky D, Chen SC. Phytosterols—health benefits and potential concerns: a review. *Nutrition Research*. 2005 May 1;25(5):413-28.
36. Phillips KM, Ruggio DM, Ashraf-Khorassani M. Phytosterol composition of nuts and seeds commonly consumed in the United States. *Journal of agricultural and food chemistry*. 2005 Nov 30;53(24):9436-45.
37. Ostlund Jr RE. Phytosterols, cholesterol absorption and healthy diets. *Lipids*. 2007 Feb;42(1):41-5.
38. Lu B, Bao J, Shan L, Zhang Y. Technology for supercritical CO₂ extraction of bamboo shoot oil and components of product. *Transactions of the Chinese Society of Agricultural Engineering*. 2009 Aug 1;25(8):312-6.
39. Choi JM, Lee EO, Lee HJ, Kim KH, Ahn KS, Shim BS, Kim NI, Song MC, Baek NI, Kim SH. Identification of campesterol from *Chrysanthemum coronarium* L. and its antiangiogenic activities. *Phytotherapy Research*. 2007 Oct;21(10):954-9.
40. Bradford PG, Awad AB. Phytosterols as anticancer compounds. *Molecular nutrition & food research*. 2007 Feb;51(2):161-70.
41. Rabrenović BB, Dimić EB, Novaković MM, Tešević VV, Basić ZN. The most important bioactive components of cold pressed oil from different pumpkin (*Cucurbita pepo* L.) seeds. *LWT-Food Science and Technology*. 2014 Mar 1;55(2):521-7.
42. Lachance PA, He YH. Hypocholesterolemic composition from bamboo shoots. *PCT International Patent PCT/US98/12556*. 1998.
43. SARANGTHEM K, NABAKUMAR SINGH T, THONGAM W. Transformation of fermented bamboo (*Dendrocalamus hamiltonii*) shoots into phytosterols by microorganisms. *Journal of food science and technology (Mysore)*. 2003;40(6):622-5.
44. Xu G, Shi Z, Zhao Y, Deng J, Dong M, Liu C, Murugadoss V, Mai X, Guo Z. Structural characterization of lignin and its carbohydrate complexes isolated from bamboo (*Dendrocalamus sinicus*). *International journal of biological macromolecules*. 2019 Apr 1;126:376-84.
45. Sharma S, Sharma A, Mulla SI, Pant D, Sharma T, Kumar A. Lignin as potent industrial biopolymer: an introduction. *Lignin: biosynthesis and transformation for industrial applications*. 2020:1-5.
46. Qin Z, Liu HM, Gu LB, Sun RC, Wang XD. Lignin as a natural antioxidant: Property-structure relationship and potential applications. *Reactive and Functional Polymers Volume One: Biopolymers, Polyesters, Polyurethanes, Resins and Silicones*. 2020:65-93.
47. MANAMOONGMONGKOL K, SUWAPANICH R, PHUMJAN L, NARKRUGSA W, SRIPROM P. Production of Cellulose From Bamboo Shoot Shell Using Hydrothermal Technique. *Journal of the Japan Institute of Energy*. 2021 Dec 20;100(12):307-12.



**Izaz Hussain et al.,**

48. Zhang A, Zou Y, Xi Y, Wang P, Zhang Y, Wu L, Zhang H. Fabrication and characterization of bamboo shoot cellulose/sodium alginate composite aerogels for sustained release of curcumin. *International Journal of Biological Macromolecules*. 2021 Dec 1;192:904-12.
49. Yang Y, Fan F, Xie J, Fang K, Zhang Q, Chen Y, Cao X, Deng Z. Isolation and characterization of cellulosic fibers from bamboo shoot shell. *Polymer Bulletin*. 2023 Feb;80(2):1817-29.
50. Park EJ, Jhon DY. Effects of bamboo shoot consumption on lipid profiles and bowel function in healthy young women. *Nutrition*. 2009 Jul 1;25(7-8):723-8.
51. Ballhorn DJ, Kautz S, Rakotoarivelo FP. Quantitative variability of cyanogenesis in *Cathariostachys madagascariensis*—the main food plant of bamboo lemurs in southeastern Madagascar. *American Journal of Primatology: Official Journal of the American Society of Primatologists*. 2009 Apr;71(4):305-15.
52. Australia FS, Zealand FN, Zealand AN. Cyanogenic glycosides in cassava and bamboo shoots.
53. Schwarzmaier U. Cyanogenesis of *Dendrocalamus: taxiphyllin*. *Phytochemistry*. 1977 Jan 1;16(10):1599-600.
54. Nartey F, Smith R, Bababumni E. Toxicological aspects of cyanogenesis in tropical foodstuffs. *Toxicology in the Tropics*. 1980:53-73.
55. Satya S, Bal LM, Singhal P, Naik SN. Bamboo shoot processing: food quality and safety aspect (a review). *Trends in Food Science & Technology*. 2010 Apr 1;21(4):181-9
56. Vetter J. Plant cyanogenic glycosides. *Toxicon*. 2000 Jan 1;38(1):11-36.
57. Seigler DS. Cyanide and cyanogenic glycosides. *CS Rosenthal & MR Berenbaum*. 1991:35-77.
58. Aguilar F, Autrup H, Barlow S, Castle L, Crebelli R, Dekant W, Engel KH, Gontard N, Gott D, Grilli S, Guertler R. Opinion of the Scientific Panel on Food Additives, Flavourings, Processing Aids and Materials in contact with Food (AFC) on a request from the Commission related to Flavouring Group Evaluation 5, Revision 1 (FGE. 05Rev1): Esters of branched-and straight-chain aliphatic saturated primary alcohols and of one secondary alcohol, and branched-and straight-chain unsaturated carboxylic acids from chemical groups 1, 2, and 5 (Commission Regulation (EC) No 1565/2000 of 18 July 2000). *EFSA Journal*. 2008 Mar 1;6(3).
59. Rana B, Awasthi P, Kumbhar BK. Optimization of processing conditions for cyanide content reduction in fresh bamboo shoot during NaCl treatment by response surface methodology. *Journal of food science and technology*. 2012 Feb;49:103-9.
60. Australia FS, Zealand FN, Zealand AN. Cyanogenic glycosides in cassava and bamboo shoots.
61. Brown L, Rosner B, Willett WW, Sacks FM. Cholesterol-lowering effects of dietary fiber: a meta-analysis. *The American journal of clinical nutrition*. 1999 Jan 1;69(1):30-42
62. Howarth NC, Saltzman E, Roberts SB. Dietary fiber and weight regulation. *Nutrition reviews*. 2001 May 1;59(5):129-39.
63. Clark MJ, Slavin JL. The effect of fiber on satiety and food intake: a systematic review. *Journal of the American College of Nutrition*. 2013 Jun 1;32(3):200-11.
64. Ballhorn DJ, Kautz S, Rakotoarivelo FP. Quantitative variability of cyanogenesis in *Cathariostachys madagascariensis*—the main food plant of bamboo lemurs in southeastern Madagascar. *American Journal of Primatology: Official Journal of the American Society of Primatologists*. 2009 Apr;71(4):305-15.
65. Oboh G, Ademosun AO. Characterization of the antioxidant properties of phenolic extracts from some citrus peels. *Journal of food science and technology*. 2012 Dec;49:729-36.
66. Pandey AK, Ojha V. Precooking processing of bamboo shoots for removal of anti-nutrients. *Journal of Food Science and Technology*. 2014 Jan;51:43-50.





Izaz Hussain et al.,

67. Badwaik LS, Borah PK, Borah K, Das AJ, Deka SC, Sharma HK. Influence of fermentation on nutritional compositions, antioxidant activity, total phenolic and microbial load of bamboo shoot. Food Science and Technology Research. 2014;20(2):255-62.
68. Thakur K, Tomar SK. Invitro study of riboflavin producing lactobacilli as potential probiotic. LWT-Food Science and Technology. 2016 May 1;68:570-8.
69. Lachance PA, He YH. Hypocholesterolemic composition from bamboo shoots. PCT International Patent PCT/US98/12556. 1998.
70. Nongdam P. Traditional fermented bamboo shoot foods of North-East India and their characteristic natural microbial flora. In 10th World bamboo congress, Korea 2015 Sep 17 (pp. 1-13).
71. Choudhury D, Sahu JK, Sharma GD. Bamboo shoot: microbiology, biochemistry and technology of fermentation-a review.
72. Sonar NR, Halami PM. Phenotypic identification and technological attributes of native lactic acid bacteria present in fermented bamboo shoot products from North-East India. Journal of food science and technology. 2014 Dec;51:4143-8.
73. Behera P, Balaji S. Health benefits of fermented bamboo shoots: The twenty-first century green gold of northeast India. Applied Biochemistry and Biotechnology. 2021 Jun;193:1800-12..
74. Choudhury D, Sahu JK, Sharma GD. Bamboo shoot based fermented food products: a review.
75. Chauhan OP, Unni LE, Kallepalli C, Pakalapati SR, Batra HV. Bamboo Shoots: composition, nutritional value, therapeutic role and product development for value addition. International Journal of Food and Fermentation Technology. 2016;6(1):1-2.
76. Kimura Y, Suto S, Tatsuka M. Evaluation of carcinogenic/co-carcinogenic activity of chikusaku-eki, a bamboo charcoal by-product used as a folk remedy, in BALB/c 3T3 cells. Biological and Pharmaceutical Bulletin. 2002;25(8):1026-9.
77. Seki T, Kida K, Maeda H. Immunostimulation-mediated anti-tumor activity of bamboo (*Sasa senanensis*) leaf extracts obtained under 'vigorous' condition. Evidence-based Complementary and Alternative Medicine. 2010 Dec 1;7:447-57.
78. Panee J. Bamboo extract in the prevention of diabetes and breast cancer. In Complementary and Alternative Therapies and the Aging Population 2009 Jan 1 (pp. 159-177). Academic Press.
79. Nam JS, Chung HJ, Jang MK, Jung IA, Park SH, Cho SI, Jung MH. *Sasa borealis* extract exerts an antidiabetic effect via activation of the AMP-activated protein kinase. Nutrition research and practice. 2013 Feb 1;7(1):15-21.
80. Das G, Patra JK, Singdevsachan SK, Gouda S, Shin HS. Diversity of traditional and fermented foods of the Seven Sister states of India and their nutritional and nutraceutical potential: a review. Frontiers in Life Science. 2016 Oct 1;9(4):292-312.
81. Hu C, Zhang Y, Kitts DD. Evaluation of antioxidant and prooxidant activities of bamboo *Phyllostachys nigra* var. Henonis leaf extract in vitro. Journal of Agricultural and Food Chemistry. 2000 Aug 21;48(8):3170-6.
82. Fujimura M, Ideguchi M, Minami Y, Watanabe K, Tadera K. Amino acid sequence and antimicrobial activity of chitin-binding peptides, Pp-AMP 1 and Pp-AMP 2, from Japanese bamboo shoots (*Phyllostachys pubescens*). Bioscience, biotechnology, and biochemistry. 2005 Jan 1;69(3):642-5.
83. Ryou SH, Kang MS, Kim KI, Kang YH, Kang JS. Effects of green tea or *Sasa quelpaertensis* bamboo leaves on plasma and liver lipids, erythrocyte Na efflux, and platelet aggregation in ovariectomized rats. Nutrition Research and Practice. 2012 Apr 1;6(2):106-12.
84. Ma Y, Yang Y, Gao J, Feng J, Shang Y, Wei Z. Phenolics and antioxidant activity of bamboo leaves soup as affected by in vitro digestion. Food and Chemical Toxicology. 2020 Jan 1;135:110941.





Izaz Hussain et al.,

85. Moon-Hee CH, YANG JH, YANG SH, Yong-Woon KI, KI SH, Hyun-Jae SH. The anti-inflammatory and anti-Adipogenic properties of bamboo (*Sasa coreana* Nakai) leaves extract. 한국생물공학회 학술대회. 2017 Oct:228-.
86. Li X, Guo J, Ji K, Zhang P. Bamboo shoot fiber prevents obesity in mice by modulating the gut microbiota. Scientific reports. 2016 Sep 7;6(1):32953.
87. Hong EJ, Jung EM, Lee GS, Kim JY, Na KJ, Park MJ, Kang HY, Choi KC, Seong YH, Choi IG, Jeung EB. Protective effects of the pyrolyzates derived from bamboo against neuronal damage and hematoaggregation. Journal of ethnopharmacology. 2010 Apr 21;128(3):594-9.
88. Shi QT. Study on relationship between nutrients in bamboo shoots and human health, bamboo and its use (pp 338-346). In Proceedings International Symposium on Industrial of Bamboo, Beijing 1992 Dec 7.
89. Yang JH, Lim HS, Heo YR. *Sasa borealis* leaves extract improves insulin resistance by modulating inflammatory cytokine secretion in high fat diet-induced obese C57/BL6J mice. Nutrition research and practice. 2010 Apr 1;4(2):99-105.
90. Zhang Y, Yao X, Bao B, Zhang Y. Anti-fatigue activity of a triterpenoid-rich extract from Chinese bamboo shavings (*Caulis bambusae in taeniam*). Phytotherapy Research: An International Journal Devoted to Pharmacological and Toxicological Evaluation of Natural Product Derivatives. 2006 Oct;20(10):872-6.
91. Park EJ, Jhon DY. Effects of bamboo shoot consumption on lipid profiles and bowel function in healthy young women. Nutrition. 2009 Jul 1;25(7-8):723-8.
92. Liu L, Liu L, Lu B, Chen M, Zhang Y. Evaluation of bamboo shoot peptide preparation with angiotensin converting enzyme inhibitory and antioxidant abilities from byproducts of canned bamboo shoots. Journal of agricultural and food chemistry. 2013 Jun 12;61(23):5526-33.
93. Tamang JP, editor. Ethnic fermented foods and beverages of India: science history and culture. Springer Nature; 2020 Mar 2.
94. Sharma NI, Handa SH, Gupta AN. A comprehensive study of different traditional fermented foods/beverages of Himachal Pradesh to evaluate their nutrition impact on health and rich biodiversity of fermenting microorganisms. International Journal of Research in Applied Natural and Social Sciences. 2013 Aug;1:19-28.
95. Chaudhary A, Sharma DK, Arora A. Prospects of Indian traditional fermented food as functional foods. Indian J Agric Sci. 2018 Oct 1;88(10):1496-501.
96. Palika R, Dasi T, Kulkarni B, Pullakhandam R. Ethnic fermented foods and beverages of Telangana and Andhra Pradesh. Ethnic Fermented Foods and Beverages of India: Science History and Culture. 2020:561-82.
97. Pandey AK, Ojha V, Choubey SK. Development and shelf-life evaluation of value added edible. American Journal of Food Technology. 2012;7(3):363-71.
98. Das A, Nath DR, Kumari S, Saha R. Effect of fermented bamboo shoot on the quality and shelf life of nuggets prepared from desi spent hen. Veterinary World. 2013 Jul 1;6(7).
99. Sood S, Walia S, Gupta M, Sood A. Nutritional characterization of shoots and other edible products of an edible bamboo–*Dendrocalamus hamiltonii*. Current Research in Nutrition and Food Science Journal. 2013 Dec 20;1(2):169-76.
100. Choudhury M, Badwaik LS, Borah PK, Sit N, Deka SC. Influence of bamboo shoot powder fortification on physico-chemical, textural and organoleptic characteristics of biscuits. Journal of food science and technology. 2015 Oct;52:6742-8.

Table 1 Comparison of phytoconstituents of fermented and non-fermented bamboo shoot

Phytoconstituent	Comparison Factors	Fermented Bamboo Shoots	Non-Fermented Bamboo Shoots	Ref.
Phenol	Contains phenolic compounds with	Present	Present	[11]





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	antioxidant properties			
Phytosterols	Total Content & Bioavailability	May Increase	Variable	[12]
Lignin	Lower concentration due to microbial degradation	Reduced	Variable	[13]
Cellulose	Possible reduction due to enzymatic breakdown	Reduced	Variable	[14]
Taxiphyllin	Potential reduction through enzymatic hydrolysis	Reduced	Variable	[15]
Dietary Fiber	Possible increase, particularly in total, soluble and prebiotic fiber	May Increase	Variable	[16]

Table 2. Health benefits of bamboshoot

Sl. No.	Health benefits	Reference
1	Antioxidant and anti-inflammatory effects of bamboo shoot extracts	[75]
2	Antimicrobial and antifungal activities of bamboo shoot	[76]
3	Cholesterol and body weight lowering effects of bamboo leaves extract	[77]
4	Antioxidant and phenolic extract of bamboo leaves promotes digestion	[78]
5	Anti-inflammatory and anti-obesity effects of bamboo leaf extract	[79]
6	Anti-obesity activities of bamboo shoot	[80]
7	Antiapoptotic activities of bamboo shoot	[81]
8	Anticancer, antibacterial, antiviral activity of bamboo shoot fiber	[82]
9	Antidiabetic properties of bamboo leaves	[83]
10	Anti-fatigue activity of bamboo shavings	[84]
11	Cholesterol-lowering properties of bamboo shoot	[85]
12	Antihypertension effects of bamboo shoot extract	[86]
13	Bamboo shoot extract enhances the antioxidant activities	[87]
14	Bamboo lignin protects neurons from oxidative stress	[88]

Table 3. Supplemented products with bamboo shoot

Sl no.	Supplemented products	Bamboo species	Processed form	Reference
1	Crackers, Nugget, Pickle	<i>Bambusa bambos</i> , <i>B. tulda</i> , <i>Dendrocalamus asper</i> , <i>D. strictus</i>	Cooked shoots treated with vinegar	[96]





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2	Chicken Nuggets	<i>B. auriculata</i>	Shoot fermented for 2 months	[97]
3	Candy, Chutney, Chukh, Cracker, Nugget	<i>D. hamiltonii</i>	Boiled shoot	[98]
4	Biscuit	<i>B. balcooa</i>	Boiled, Dried, and Powdered	[99]
5	Chips	<i>B. vulgaris</i>	Shoot boiled for 2 hours	[100]



Figure 1. Bamboo shoot fermentation process





Internet of Nanothings for Medical Applications - A Review

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ABSTRACT

An advanced and novel part of the Internet of Things (IoT) is also termed the Internet of Nano things (IoNT). In communication networks, novel merit is depicted by the applications, which operate on the Nanoscale. In medicine as well as healthcare services, revolutionizing advancement could be brought by the IoNT, which is helping in the age of specialized healthcare monitoring systems. It is made up of tiny actuators and sensors powered by nanotechnology (NT), not uncomfortable sensing devices. The IoNTs engage with cells to regulate body dynamics, they provide improved patient care through early detection. Furthermore, medical judgments are made based on data accumulated over time, as opposed to traditional imaging examinations. In several Nano-applications in the IoNT that are from preventive treatment to diagnostics and rehabilitation, Real-Time (RT) data could be wielded. Research on IoNT has been done in medical applications like Tumour cells, Disease diagnostics, DNA sequencing, Diagnostics, etc., but in some other applications, research was not completely analyzed and unfortunately, this was considered to be a research gap.

Keywords: Internet of Nano things, Medical application, Health care, Nanodevices, and Nanosensors



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INTRODUCTION

By connecting computers, the evolution of the internet was initiated. Several computers were linked, creating the World Wide Web. After that, mobile devices could link to the Internet, resulting in the mobile-Internet methodology. People initiated employing the Internet via social networks [1]. IoT is degrading beside the constant advancements in technology, which is burgeoning as a ubiquitous global computing network in which everything would be linked to the Internet [2]. IoT is emerging as a significant technology; thus, impacting daily lives; also, it is detected to do so extensively soon. However, the concept was a little fuzzy. IoT's scholarly conceptualizations and cultivated understandings differ significantly [3]. Certainly, the internet and device deployment was changed to another device communication by the IoT, where sensors and objects communicate with one another. Various domains, namely Wireless Body Sensor Networks (WBAN) and IoNT emerged owing to IoT [4]. The microscopic devices' interconnectivity extending as of '1' to an insufficient '100' nanometres, which could access the internet as well as other communication, is termed IoNT [5]. Things acquired from Nanomaterials are termed Nano things. Convergent points in which NT, the IoT, and Industry 4.0 meet are IoNT. Also, those areas converge in sensors, which could be deployed in conventional IoT systems, especially IoT's manifestation, which is a novel solution for medical applications, is termed IoNT [6]. In one of the medical applications in healthcare, the most profound usage of IoNT was detected. The IoNT usage in health care (one of the medical applications) is elucidated in Figure 1. The IoNT concept is presented as an IoT type with 1 to 100nm Nanodevicesinterrelated with traditional networks developed by networking paradigms [8]. A few uses of IoNT in medical applications of health care are [9, 10],

- By implementing in-body Nanosensors, which simply monitor a patient's health along with physiological activity, IoNTs could be wielded for forming Body Sensor Networks (BSN).
- Patients and doctors see the data acquired by Nanosensors on a wearable gadget.
- Patients and doctors could acquire critical healthcare information in RT by engaging IoNT.
- To produce medical reports and get the effect of specific operations on a patient, information could be helpful hugely.

The IoNT offers the possibility to connect various Nanodevices using a high-speed network [11, 12]. However, the problem is that there is a chance that medical information from unauthorized access will create a serious impact on people's lives [13]. The remaining part is arranged as: the survey on the IoNT's utilizations in medical applications is elucidated in section II; the analysis is expounded in section III; the paper is wrapped up with future work in section IV.

Internet of Nanothings Evolution And Current Scenario

For each particular application, several nanotechnologies incorporated into an IoNT system could be deployed. A smart digitized healthcare system that links present medical resources and healthcare services is caused by the IoT. Here, section A implies the survey on IoNT; section B explains the use of IoNTs in medical applications; section C describes the comparison of the utilization of IoNTs in medical applications, and section III delineates the potential research problems emerging for the IoNT field in medical applications.

IoNT

The interconnection of Nanodevices with prevailing networks is termed the IoNTs. Hence, in electromagnetic communication areas amongst Nano-scale devices, a prevailing revolution was created. For performing various tasks, Nanomachines are incorporated with Nano components [14]. In spanning environments, agriculture health, and packaging, IoNT could be deployed. IoNT's value will be augmented by implementing it in every application [15, 16]. **Keyvan, et al. [17] developed** multi-user molecular communication in IoNTs. With augmented modulation in the transmitter pump molecules, the Binary Direction Shift Keying (BDSK) was implemented in '2' diverse directions. Regarding achievable data rate, this system surpassed other modulation techniques; also, this methodologies' realizable rate had a peak in symbol duration specific value. However, when weighed against other





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modulation kinds, this system wasn't bandwidth-efficient modulation. **Sebastian, et al. [18]** elucidated the development of the ideal transmission policy intended for IoNT flow-guided Nano-sensor devices. A general Markov Decision Process (MDP) was implemented, which could be used to derive the best transmission policies, which Nano-nodes could then use. As per the evaluation, the remaining policies were surpassed by this one by a large margin along with precision in placing Nano-routers. Moreover, the Nano-network performance was hugely affected by the average distance between them. This specific IoNT sort of environment was coined as a flow-guided environment; also, it wasn't trouble-free. **Fadi, et al. [19]** explained the Rational Data Delivery Algorithm (RDDA) for disaster-inspired IoNT in practice. For the IoNT, this system was implemented as a distinguished routing protocol. Multitier Nano network and cluster/tier-wide synchronization were assumed. As per the outcomes, when analogized to other '2' alternatives, the system's fairness was high. In deciding the next hop, the above-depicted learning and reasoning elements were deployed; thus, among the available Routing Nodes (NRs), the processed requests were distributed evenly. **Sonu, et al. [20]** described the intelligent plant pathogen-diagnostic Biosensors (BS) paradigm influenced by the Internet of Things. It was augmented by the incorporation of Nano BSs with Artificial Intelligence (AI), cloud computing, IoT, 5G communication, along drones. As per the outcomes, the determination of the virus-associated element as well as protein was linear up to 50 viral elements / 100 ml⁻¹ ($R^2 = 0.93$) and 53 pg. ml⁻¹ ($R^2 = 0.99$) in pH7. **Wojciech, et al. [21]** delineated the special problem of progressions in 5G network security for IoNT. For the 5G foundation, secure network architectures, protocols along mechanisms were significant for handling potential security threats. The connectivity provider's core network load was minimized. The implemented solution was feasible; also, it permits cellular networks to surpass security limitations.

Challenges in IoNT's

IoNT is the underrated Nano sensor network, which has a high potential to be espoused in RT applications [22, 23]. IoNT has a few issues that have to be tackled to permit it to be a crucial segment without any constraints even though it offers unlimited benefits [24, 25]. The challenges in IoNTs with their contributions and findings are elucidated in Table I. **Sree Lakshmi, et al. [32]** described the security and possible challenges and applications for IoNTs in the near future. The main objective was to include a detailed view of IoNT, application areas, and the methods to overcome prevailing challenges along with making use of IoNT soon. Huge execution and versatility issues would be caused by IoNT protections. In Nanomachines, there would be huge asset impediments, which make Nano correspondence that was unrivaled in present correspondence techniques. **Falko Dressler, et al. [33]** investigated the IoNT's challenges along with opportunities in body Nano communication with body area networks. A network system that supports the resulting requirements was derived. A scenario that was apt for biomedical application was assumed. In specific simulation-centric performance evaluation along with security problems, problems were detected by employing this network. **Sasitharan, et al. [34]** elucidated the challenges and requirements for realizing IoNTs. The challenges were classified into 3 types, such as data collection, IoNT middleware, and future outlook. Here, data collection includes architecture and routing, IoNT middleware includes Self-awareness, Data analysis, and processing, Energy conservation through synchronization and outlook including security and privacy, as well as Service Composition and Discovery. Analysis indicated new directions and opportunities in end-user computing that use Nanosensors embedded in their environment.

Ke Yang, et al. [35] explained the inclusive study on hybrid communication for IoNTs in a body-centric communication context. To apprehend the hybrid technologies' possibility, the technologies were enabled. As per the evaluation, in IoNT, the Bit Error Probability (BEP) augments as either the molecules per bit augment or else the code word minimal distance minimizes. **Hasan, et al. [36]** elucidated the IoNT as the next step for the future of NT. Since the transition from macro to Nano was unavoidable, the major issues essential to be verified by the working agency on Nano have to be faced. As per the evaluation, a world where innovative products were framed at the microscopic and molecular level was detected by NT; also, for IoNT and renewable energy sources, it delivers precise as well as cost-effectual methods. **Jussi, et al. [37]** realized the IoNTs with their challenges, solutions, and applications. Same as like others, challenges were categorized into 3 types. Gathering data at fine-grained (microscopic) levels from several sources along with context schemes would be made possible by the IoNT. As per the evaluation, for securing





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sensitive data in IoNT collected by Nanosensors that encompass full chemical and biological samples from individuals, security and privacy techniques might be still required.

Use of IoNT in the Medical Applications

For augmenting the device's functionality, energy efficiency, and accuracy, espousing Nanomaterials within IoT devices could deploy exceptionable properties whilst minimizing the size [38, 39]. Game-changing possibilities will be brought by IoNT to medical practice [40, 41]. The use of IoNTs with its results attained with its disadvantages is elucidated in Table II. **AMIT BANERJEE, ET AL. [50]** explained the MRI, AI, IoT, IoNT, as well as wearable devices in terahertz (THz) healthcare technologies. For THz spectroscopy, constructing a comprehensive database meant for biomolecule recognition is significant. As per the evaluation, the analytical data's accuracy and reproducibility were enhanced; also, RT acquisition speed not only augmented signal-noise ratios but also augmented the solid state with high power, safe, and sophisticated systems. However, owing to a lack of enabling components, THz imaging has not been widely focused. **FarhadAhamed, et al. [51]** used machine learning and the Internet of Things to provide individualized healthcare for the problems. It was easy to create a risk classification using predictive analysis, whereby certain patients who posed a greater risk required more attention. In the available dataset, factors can emerge where the computers would be wielded to train to make a decision. This was a significant issue for the dataset. **Ravina, et al. [52]** explained the inkjet-printed nanomaterial-centric flexible Radio Frequency Identification (RFID) tag sensors for the IoNTs. In IoT and IoNT emerging fields, the inkjet-printed RFID tag sensors' role was evaluated. Smartphones and cloud computing technology were deployed by the grapheme Nanosensors-centric IoNT system; also, while performing multi-gas sensing activity with NFC/RFID tag sensor, extremely lower power (8.5 mW) was deployed by the RFID when using an NFC-enabled smartphone. **Weisi Guo, et al. [53]** secured the IoNT for the targeted drug delivery. For implementing cipher keys engendered as dynamic molecular channel statistics for encryption, a fast advance in radio Physical Layer Security (PLS) was leveraged. When analogized to the intended transmission channel, this system could acquire a higher eavesdropper Key Disagreement Rate (KDR) of 5-7. The message could not be deciphered by any potential malicious eavesdropper. Thus, it can't do malicious actions. **Mirjana, et al. [54]** outlined the use of IoNTs and nanofood in medical applications. A variety of data mining techniques, artificial intelligence, and statistical analysis were used to weed out the useful information from the many types of data that were collected. As per the outcomes, for augmenting productivity, customized, low-cost, powerful, safe, together with comfortable, Nanodevices and G-IoNT could enable constant and RT monitoring of critical parameters; thus, satisfying the augmented society's demands for safe as well as quality food.

Comparison of Utilization of IONT's in the Medical Applications

Contrarily, in a medical application, IoNT was applied with the aim of biological communications [55]. For performing operations like intra-body sensing, actuation, and connectivity control, biological cells are controlled under IoNT with the medical application by deploying biochemical stimuli [56]. Ultimately, an IoNT should eradicate a Nano device or else set of Nanodevices as of its network while their usefulness was outlived [57]. Looking at how natural biological systems perform this function is normal as those Nanodevices are engineered as of biological components; also, they are hugely deployed in medical applications [58]. The comparison of the utilization of IoNT in medical applications with its findings and disadvantages are elucidated in Table III. **Sidra Zafar, et al. [64]** developed the thorough evaluation of bio-cyber interface technologies as well as IoNT security concerns. Because IoNTs have a dynamic interface architecture that makes it easier to convert biochemical signals from the human body into similar electromagnetic signals, they have played a significant role in bridging the gap between the biological environment and technology. The applied system attained efficient results by employing molecular communication and Nano electromagnetic communication in parallel for Nano-micro interfacing. **Alper, et al. [65]** described the healthcare and patient monitoring in IoNT. For patients (A) pulse rate, (B) plethysmogram, together with (C) relative oxygen ratio, this system aims particularly at the data. This technique was (a) reliable, (b) feasible, as well as (c) self-configurable. When compared to the wired system, the data accuracy was at the intended level. Minimal interference with other 2.4 GHz systems, such as Bluetooth and Wi-Fi, did not affect the accuracy of the system's operation. **Valeria, et al. [66]** described the security as well as privacy in molecular communication along with the networking of IoNTs. In many diverse applications that range from military to health environments, security, and privacy were





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very vital as well as crucial factors. The outcomes exhibited that there were improvements regarding theoretical foundations associated with DNA together with the technological progress that will permit making DNA feasible regarding costs as well as low complexity. **Jacek, et al. [67]** explained the IoNTs in the healthcare network. The analyses were assisted with the outcomes of tests of a Nanosensors network operating in the human circulatory system. Analysis exhibited that comparison of delay characteristics signified that the delays were satisfactory in both the first and second cases- less than 1/3 microsecond in the worst case as well as 0.5 Picosecond in the better case. The Nano-node's implemented energy methodology was not incorporated into the model. **Ali Rizwan, et al. [68]** explained the Nano-communication role in IoNT's upcoming healthcare systems. Big data analytics was used to gather intelligence from the massive amounts of healthcare data needed for futuristic smart healthcare in order to solve relevant issues and take advantage of opportunities. It was made to sense the glucose level in the tears via contact lenses due to the advances in Nanoscale technology.

Summary

By the interconnection of Nanoscale devices with the prevailing Internet communication networks, a new networking system termed the IoNT is characterized. The incorporation of information and communication technologies combined with medical and Nano-bio sciences is termed the Internet of Bio-Nano Things. Modern telemedicine is dependent on tiny and high level functional medical electronic related implantable as well as wearable devices, which are engineered via NT. It had been clear from many findings that while applying IoNT in some of the medical applications, such as disease diagnostics and MRI, etc., it attained better accuracy and efficiency; IoNT BAN also achieved better results in most of the medical applications. However, it cannot be concluded that the IoNT had only the advantages in the medical applications because, for every technology, there will be some advantages as well as disadvantages. Limitations of applying IoNT in medical applications include the extension of time length, metrics throughput being limited by a refractory period, and some of the major issues related to FMR that were not solved.

Potential Research Problems Emerging For The Field Of Internet Of Nano Things In Medical Applications

IoNT is considered as a screening technique, where genetically engineered bacteria are inserted into the body of a respondent, which would find the tumor and release the fluorescent marker [69, 70]. However, in medical applications, there are some of the basic potential research issues identified from the survey of IoNT. In medical applications, the research problems from the survey for IoNT were categorized into 2 types infrastructural and security. The list of research problems obtained for the infrastructural and security of IoNT in medical applications is elucidated in Table IV. Some of the major research problems of IoNT like planning the problems, no strong passwords, failure to predict threats and user privacy, etc. have been discussed in Table 4. Smart hospital management system has several issues even though it offers betterment of life quality of people due to their different application in a health-related system. Thus, an IoNT architectural design, which handles the elucidated issues, is required; also, it should offer a communication system with those devices, which is attainable and consistent [75]. The percentage of comparison of research problems obtained for infrastructural and security of IoNT in medical applications is elucidated in Table V. Out of the three research problems like weak default passwords, lack of predicting threats, and user privacy; Weak default passwords indicated about 50%, which means half of the problem was this, which is depicted in Table V.

CONCLUSION

IoNT bears the promise of novel devices that could communicate and help daily lives toward wearable technologies that mandate adaptable integration like wireless body networks (WBN), health monitorization, and sensing. In several medical applications, the enhancement of Nanotechnologies, Nanomachines, and IoNT will have a huge effect on advanced development soon. Those applications range from early symptom detection to remote diagnosis to patients' treatments (for example, through targeted drug delivery), etc. When compared with the other mentioned models, IoNT stands unique. However, even though the technologies were enhanced in the IoNT, in many places, the





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medical information got attacked by unauthorized access when utilizing the IoNT in medical applications. Thus, future researchers should consider this limitation and find an appropriate solution. Healthcare providers will be aided by IoNT for leveraging on-time treatment and making accurate decisions in the future. Those IoT-centric devices with abilities, namely RT alerting, tracking, and monitoring permit doctors to give hands-on treatment with superior accuracy and remotely enhance patient care systems. Further, for resolving redundant sensory data problems can be recovered by wearable sensor devices, a re-enforcement algorithm would be developed with IoNT-enabled healthcare infrastructure. Digital medical, as well as healthcare applications, now let patients schedule their appointments without the requirement of a doctor or waiting for the receptionist. In the future, the IoNT uses in medical applications through online connections will double from now in the future.

REFERENCES

1. S. A. Korade, V. Kotak, and A. Durafe, A review paper on Internet of Things (IoT) and its applications, *"International Research Journal of Engineering and Technology"*, 2019. vol. 6(6), pp. 1623-1630.
2. T. Mufti, N. Sami, and S. S. Sohail, A review paper on Internet of things, *"Iind J. Appl. Res."* 2019. vol. 9(8) pp. 24–25.
3. M. Akerlund and D. Nylen, "From technology speculation to value creation the changing discourse and actants in the construction of IoT on Twitter," *"Peer Rev. J. Internet"*, 2019. vol. 26, pp. 1–24.
4. K. Hasan, K. Biswas, K. Ahmed, N. S. Nafi, and M. S. Islam, A comprehensive review of wireless body area network, *"Journal of Netw. Comput. Applications"*, 2019 vol. 143, pp. 178–198.
5. B. Nagajayanthi, *Decades of Internet of things towards the twenty-first century: "A research-based introspective"*, 2022, vol. 123(4).
6. Nikhat Akhtar and Yusuf Perwej, The Internet of Nano things (IoNT) existing state and future Prospects, *"GSC Adv. Res. Rev."* 2020, vol. 5,(2), pp. 131–150.
7. O.-M. E, M. M, and V. V, The future of healthcare: Nanomedicine and internet of Nano things, *"ArXiv"*, 2015. pp. 1–7.
8. E. Almazrouei, R. M. Shubair, and F. Saffre, Internet of Nanos things: Concepts and Applications, *"ArXiv"*, 2018. pp. 1–42
9. S. Prajapati, Applications of the Internet of Nano Things, *"Analytic Steps"*, 2021
10. Onio, An Introduction to the Internet of Nano Things, 2021.
11. F. 40, "Internet of Nano things market 2022 industry analysis |including 99 pages report Internet of Nano things market 2022 industry analysis including 99 pages report," WICZ TV, 2022.
12. M. Prakasam and M. Jhanani, "Internet of Nano Things: The World Wide Techno Component Next," *Int. Adv. Res. J. Sci. Eng. Technol.*, 2018, vol. 5(1), pp. 18–22.
13. M. Z. Ahmed, L. Physics, and O. C. A, "Internet of Nano things: The worldwide techno component next," *Int. Adv. Res. J. Sci. Eng. Technol.*, 2018.vol. 5(1), pp. 727–732.
14. M. R. Malasa, A Tera Hertz Graphene Based Antennas for Internet of, *"IJRAR"*, 2019, vol. 6(2)pp.131–134.
15. P. Kethineni, Applications of Internet of Nano things: A survey, "in 2017 2nd International Conference for Convergence in Technology", I2CT 2017, pp. 371–375. Doi
16. A. Nayyar, V. Puri, and D.-N. Le, Internet of Nano things (IoNT): next evolutionary step in nanotechnology, *"Nanoscience. Nanotechnology"*. 2017.vol. 7(1), pp. 4–8.
17. K. Aghababaiyan, H. Kebriaei, V. Shah-Mansouri, B. Maham, and D. Niyato, Enhanced Modulation for Multiuser Molecular Communication in Internet of Nano Things, *"IEEE Internet Things J"*., vol. 9(20), 2022, pp. 19787–19802.
18. S. Canovas-Carrasco, R. M. Sandoval, A. J. Garcia-Sanchez, and J. Garcia-Haro, Optimal transmission policy derivation for IoNT flow-guided Nano-sensor networks, *"IEEE Internet Things J."*, 2019, vol. 6(2), pp. 2288–2298.
19. F. Al-Turjman, A rational data delivery framework for disaster-inspired internet of Nano-things (IoNT) in practice, *"Cluster Comput."*, 2019.vol. 22(1), pp. 1751–1763.





Manga and Kishor Sonti

20. Sonu and V. Chaudhary, A Paradigm of Internet-of-Nano-Things Inspired Intelligent Plant Pathogen-Diagnostic Biosensors, *"ECS Sensors Plus"*, 2022. vol. 1(3), pp. 1–6.
21. W. Mazurczyk, P. Bisson, R. P. Jover, K. Nakao, and K. Cabaj, Special issue on Advancements in 5G Networks Security, *"Future. Gener. Comput. Syst."*, 2020. vol. 110, pp. 314–316.
22. H. F. Atlam, R. J. Walters, and G. B. Wills, Internet of Nano things: Security issues and applications, in *"ACM International Conference Proceeding Series"*, 2018. pp. 71–77.
23. O. Ali, M. K. Ishak, and M. K. L. Bhatti, Emerging IoT domains, current standings, and open research challenges: A review, *"PeerJ Comput. Sci."*, 2021. vol. 7, pp. 1–49.
24. R. Buyya and A. V. Dastjerdi, Internet of Things Principles and Paradigms, *"Elsevier"*, 2016.
25. L. Farhan *et al.*, Energy Efficiency for Green Internet of Things (IoT) Networks: A Survey, *"Network"*, 2021. vol. 1(3), pp. 279–314.
26. Z. S. Ageed *et al.*, A State of Art Survey of Nano Technology: Implementation, Challenges, and Future Trends, *"Asian J. Res. Comput. Sci."*, 2021. vol. 10(3), pp. 65–82.
27. A. O. Balghusoon and S. Mahfoudh, Routing Protocols for Wireless Nanosensors Networks and Internet of Nano Things: A Comprehensive Survey, *"IEEE Access"* 2020., vol. 8, pp. 200724–200748.
28. I. Lakshmi, Internet of Nano Things (IoNT): Next Organic Process Step in Technology, *"Int. J. Res. Anal. Rev."*, 2018. vol. 5(3), pp. 1–10.
29. M. S. Solanki and M. M. Nayak, Survey on Internet of Nano things, *Int. J. Electr. Eng. Technol.*, vol. 11(10), 2020. pp. 275–280.
30. Murat Kuscü and Bige Deniz Unluturk, Internet of Bio-Nano Things: A Review of Applications, Enabling Technologies and Key Challenges, *"ITU J. Future. Evol. Technol."*, vol. 2(3), 2021. pp. 1–24.
31. N. A. Ali and M. Abu-Elkheir, Internet of Nano-things healthcare applications: Requirements, opportunities, and challenges, in *"IEEE 11th International Conference on Wireless and Mobile Computing, Networking and Communications"*, 2015. pp. 9–14.
32. S. Manojkumar, Security and possible applications towards internet of Nano things in near future, *"Int. J. Electron. Devices Netw."*, 2022, vol. 3(2), pp. 36–42.
33. F. Dressler and S. Fischer, Connecting in-body Nano communication with body area networks: Challenges and opportunities of the Internet of Nano Things, *"Nano Commun. Netw."*, 2015, vol. 6(2), pp. 29–38.
34. S. Balasubramaniam and J. Kangasharju, Challenges and requirements towards realizing Internet of Nano things, *"IEEE"*, 2013.
35. Yang *et al.*, A Comprehensive Survey on Hybrid Communication for Internet of Nano-Things in Context of Body-Centric Communications, *"ArXiv"* 2019., pp. 1–26.
36. H. Rafael, S. W. Jamil, M. I. Aslam, and I. Ahmed, Internet of Nano Things: Next Step for Future of Nanotechnology, *"4th International Electrical Engineering Conference"*, 2019, pp. 1–8.
37. S. Balasubramaniam and J. Kangasharju, Realizing the Internet of Nano things: Challenges, solutions, and applications, *"Computer (Long. Beach. Calif)"*, 2013. vol. 46, (2), pp. 62–68.
38. Pod more, Integrating Nanotechnology into the Internet of Things, *"AZO Nano"*, 2022.
39. V. Rastogi *et al.*, Carbon Nanotubes: An Emerging Drug Carrier for Targeting Cancer Cells, *"J. Drug Deliv."*, 2014. vol. 23, pp. 1–23.
40. D. Verma *et al.*, Internet of things (IoT) in Nano-integrated wearable biosensor devices for healthcare applications, *"Biosens. Bioelectron X"*, 2022. vol. 11, pp. 1–17.
41. J. Qi, P. Yang, G. Min, O. Amft, F. Dong, and L. Xu, Advanced Internet of things for personalized healthcare systems: A survey, *"Pervasive Mob. Comput"*, 2017. vol. 41, pp. 132–149.
42. N. A. Ali, W. Alexander, and M. Abuelkhair, Internet of Nano-Things network models and medical applications, *"International Wireless Communications and Mobile Computing Conference"*, 2016. pp. 211–215.
43. Zvezdana Gavrilovic and M. Maksimović, Nanomedical devices as a tool for consumer research. 2020.
44. V. Chaudhary *et al.*, Internet-of-Nano-things (IoNT) driven intelligent face masks to combat airborne health hazard, *"Mater. Today"*, 2022, vol. 60, pp. 201–226.





Manga and Kishor Sonti

45. G. Piro, G. Boggia, and L. A. Grieco, On the design of an energy-harvesting protocol stack for Body Area Nano-Networks, "*Nano Commun. Netw.*", 2015. vol. 6(2), pp.74–84.
46. F. Akyildiz, M. Pierobon, S. Balasubramaniam, and Y. Koucheryavy, The internet of bio-nanotechnology, "*IEEE Commun. Mag.*", 2015, vol. 53, (3), pp. 32–40.
47. Maksimović, The roles of nanotechnology and internet of Nano things in healthcare transformation, "*Technological*", vol. 20, (40), pp. 139–153, 2017.
48. S. Sicari, A. Rizzardina, G. Piro, A. Coen-Porisinia, and L. A. Grieco, Beyond the smart things: Towards the definition and the performance assessment of a secure architecture for the Internet of Nano-Things, "*Comput. Networks*", 2019. vol. 162, pp. 1–36.
49. F. Al-Turjman, A Cognitive Routing Protocol for Bio-Inspired Networking in the Internet of Nano-Things (IoNT), "*Mob. Networks Appl.*" 2020. , vol. 25(5), pp. 1929–1943..
50. A. Banerjee, C. Chakra Borty, and M. Rathi, *Medical Imaging, Artificial Intelligence, Internet of Things, Wearable Devices in Terahertz Healthcare Technologies*, "Elsevier Inc.", 2020.
51. F. Ahamed and F. Farid, Applying Internet of things and machine-learning for personalized Healthcare: Issues and challenges, "*Proceedings - International Conference on Machine Learning and Data Engineering*", 2018, pp. 22–29.
52. R. Singh, E. Singh, and H. S. Nalwa, Inkjet-printed nanomaterial-based flexible radio frequency identification (RFID) tag sensors for the internet of Nano things, "*RSC Adv.*", vol. 7(77), pp. 48597–48630.
53. W. Guo, Z. Wei, and B. Li, Secure internet-of-Nano things for targeted drug delivery: Distance-based molecular cipher Keys, "*Middle East Conference on Biomedical Engineering*", 2020. pp. 1–6.
54. Maksimović, Enisa Omanović-Miklićanin, and A. Badnjević, *Nanofood and Internet of Nano things*. 2019.
55. A. Abbasi and O. B. Akan, "An Information Theoretical Analysis of Human Insulin-Glucose System Toward the Internet of Bio-Nano Things," *IEEE Trans. Nano bioscience*, 2017. vol. 16(8), pp. 783–791.
56. M. Kuscus and O. B. Akan, "Modeling convection-diffusion-reaction systems for microfluidic molecular communications with surface-based receivers in the Internet of Bio-Nano Things," *PLoS One*, 2018. vol. 13(2), pp. 1–19,
57. A. El-Fatyany, H. Wang, S. M. Abd El-atty, and M. Khan, Biocyber Interface-Based Privacy for Internet of Bio-Nano Things, "*Wirel. Pers. Commun.*", 2020. vol. 114(2), pp. 1465–1483.
58. U. A. K. Chude-Okonkwo, R. Malekian, B. T. Maharaj, and C. C. Chude, "Bio-inspired approach for eliminating redundant Nanodevices in the internet of bio-Nano things," *IEEE Globecom Workshops, GC Wkshps*" 2015. , pp. 1–6.
59. Kulakowski, K. Turbic, and L. M. Correia, "From Nano-Communications to Body Area Networks: A Perspective on Truly Personal Communications," *IEEE Access*, vol. 8, pp. 159839–159853, 2020, doi: 10.1109/ACCESS.2020.3015825.
60. F. Al-Turjman, Intelligence and security in big 5G-oriented IoNT: An overview, "*Futur. Gener. Comput. Syst*" 2020. , vol. 102, pp. 357–368.
61. R. S. Prabhat, D. S. Ananthi, S. Rajasoundarya, R. Janakan, and R. Priyanka, Internet of nanotechnology (IoNT) -a concise review of its healthcare applications and future scope in pandemics, "*Int. J. Pharm. Sci. Med.*", vol. 6(10), pp. 1–15, 2021..
62. B. F. Maphathe, P. Thakur, G. Singh, and H. E. Iddi, "The Terahertz Channel Modeling in the Internet of Multimedia Design In-Body Antenna," *Int. J. E-Health Med. Commun.*, 2022. vol. 13(4), pp. 1–17.
63. F. Afsana, S. A. Mamun, M. S. Kaiser, and M. R. Ahmed, Outage capacity analysis of cluster-based forwarding scheme for Body Area Network using Nano-electromagnetic communication, "II-International Conference on Electrical Information and Communication Technologies, EICT 2015", 2015, pp. 383–388.
64. S. Zafar *et al.*, A systematic review of bio-cyber interface technologies and security issues for the internet of bio-Nano things, "*IEEE Access*", 2021. vol. 9, pp. 93529–93566.
65. M. A. Akkaş, R. SOKULLU, and H. Ertürk Cetin, "Healthcare and patient monitoring using IoT," *Internet of Things*, vol. 11, pp. 1–12, 2020, doi: 10.1016/j.iot.2020.100173.
66. V. Loscri *et al.*, Security and Privacy in Molecular Communication and Networking: Opportunities and Challenges to cite this version : HAL Id : hal-01071562 Security and Privacy in Molecular Communication and





Manga and Kishor Sonti

Networking : Opportunities and Challenges, "IEEE Trans. Nano Basic. Inst. Electr. Electron. Eng".2015., vol. 13(3), pp. 198–207.

67. Jarmakiewicz, K. Parobczak, and K. Maslanka, On the Internet of Nano Things in healthcare network, "Int. Conf. Mil. Common. Inf. Syst".2016., pp. 1–6..

68. Rizwan *et al.*, "A Review on the Role of Nano-Communication in Future Healthcare Systems: A Big Data Analytics Perspective," *IEEE Access*, 2018. vol. 6, pp. 41903–41920.

69. T. Panteli, N. Van Dessel, and N. S. Forbes, "Detection of tumors with fluoromarker-releasing bacteria," *Int. J. Cancer*, 2020. vol. 146(1), pp. 137–149.

70. Lo, K. Bhardwaj, and R. Marculescu, "An autonomous and adaptive bacteria-based drug delivery system," in *Proceedings of the 3rd ACM International Conference on Nanoscale Computing and Communication*, 2016, pp. 1–6.

71. Vosikas, "Cyber security in the Internet of Medical Things. Risks and Challenges," 2020. [Online]. Available:<http://www.theseus.fi/handle/10024/379781>

72. H. Fouad, M. Hashem, and A. E. Youssef, A Nano-biosensors model with an optimized bio-cyber communication system based on Internet of Bio-Nano Things for thrombosis prediction, "J. Nanoparticle Res",2020.vol. 22(7), pp. 1–17.

73. Prosperi *et al.*, Causal inference and counterfactual prediction in machine learning for actionable healthcare, "Nat. Mach. Intell".2020. vol. 2(7), pp. 369–375.

74. M. U. Rahman, Q. H. Abbasi, N. Chopra, K. Qaraqe, and A. Alomainy, Physical Layer Authentication in Nano Networks at Terahertz Frequencies for Biomedical Applications,"*IEEE Access*", 2017. vol. 5, pp. 7808–7815.

75. H. Almotairi, Application of Internet of things in the healthcare domain, "J. Umm Al-Qura Univ. Eng. Archit",2022. pp. 1–12.

Table 1: Challenges in Iont’s with their Contributions and Findings

Author Name	Work On Topic	Challenges Mentioned	Findings
Zainab, et al. [26]	Art of survey on NT with challenges and future trends	Security, Compatibility, and Bandwidth	Results indicated that lowering the size of the receptive field in neural networks (NNs) of IoNT could reduce training time by 5-7 percent while preserving network accuracy.
AREEJ, et al. [27]	Routing Protocols for Wireless Nanosensor Networks and IoNT’s	Routing Technology	As per the implemented routing using Nano-Sim’s simulation outcomes, the system’s efficacy was proved in network reliability and energy savings.
Dr.I.Lakshmi, et al. [28]	New organic process step in IoNT through NT	Security and privacy issues	The development of Nanotechnologies, Nanomachines, and IoT, along with IoNT analysis created an excellent impact on advanced development in virtually each field
Madhav, et al. [29]	Deep survey on IoNT with application and challenges	Key management, Performance, and scalability	Analysis showed that the growth of IoNT, IoT, and Nanomachines will have a great effect on technological technology
Murat, et al. [30]	IoNT’s with general applications and key challenges	Communication Methods and Energy Conservation	As per the experimentations done on macro- and micro-scales in IoNT, a higher level of nonlinearity was caused by the characteristics of sensors deployed as receivers.
Najah, et al.	IoNT’s healthcare	Content Management	





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[31]	applications with requirements and challenges	A wave-, a bit-, and a packet-levels were the 'e' integrated components.
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Table 2: Use of Iont's with Its Results Attained with its Disadvantages

Author Name	Medical Applications	Findings	Limitations
Najah, et al. [42]	Tumor cells	The evaluation results provided insight into the positives and negatives of the '2' key aspects of protocol designs; in addition, permit for detection of the protocol kind, which was a better fit for combating the constraints of Nanodevices	As the molecules were the medium, that carried the information, how congestion would be evaded was not clear in molecular communication.
Zvezdana, et al. [43]	Magnetic resonance imaging (MRI)	Analysis indicated that the IoNT was likely to enhance as of USD 6.42 billion in 2017 to 22.04 billion by 2023, at a CAGR of 22.81%	Potential Nontoxicity, Greenhouse emissions, Increased waste quantities, or else the consumption of non-renewable raw materials
Vishal Chaudhary, et al. [44]	Disease diagnostics	As per the outcomes, the requirement for smart along with sustainable techniques for integrating 5th-generation IoNTs into FMRs, namely the usage of green materials together with strategies for fabricating their components.	Issues related to face masks-respirators (FMR) remain unsolved
Giuseppe, et al. [45]	Diagnostics	Reported results showed that sizing the healthcare monitoring system regarding request rate along with network size as per Nano-medical application requirements might be helpful.	Regulating the interaction between macro and Nanodevices properly wasn't clear.
I. F. Akyildiz, et al. [46]	DNA sequencing	From the results, a situation in which IoBNT includes various networks was wielded in the human body along with interfaces via a personal electrical device.	Higher latency, lack of standardized response, low selectivity, along with unknown biocompatibility
Mirjana, et al. [47]	Cancer	From analysis, in achieving accuracy and efficiency, a key role will be played by NT and the IoNT.	For protecting the IoNT, prevailing security solutions were not apt; thus, signifying the requirement for novel and suitable security and privacy frameworks and mechanisms.
S. Sicari, et al. [48]	Drug delivery, Gene delivery, and Molecular diagnostics	As per the evaluation done by Nano-Sim together with N3Sim tools, considerable outcomes were depicted to analyze the implemented secure approach's impact in the IoNT context.	It wasn't mature enough to be incorporated with challenging protocols.





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Fadi, et al. [49]	Diagnostics	It was clear that Enhanced Energy-Efficient algorithm outperformed other algorithms. That was due to the lower failure rate experienced in which the failed transmissions as the algorithm were less than the others by at least 10%.	Applied methods sometimes may not be applicable for Nanonetworks.
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Table 3: Comparison of the Utilization of Iont in Medical Applications with its Findings and Disadvantages

Author Name	Networking Domain	Findings	Limitations
PAWEL, et al. [59]	IoNT with body area network (BAN)	Potential mechanisms, which could be exploited for offering interfaces betwixt Nano- along with micro-scale systems and BANs were detected by the evaluation.	By the refractory period (after the action potential broadcast while the neuron didn't respond to any inspiration), the achievable throughput was constrained.
Fadi, et al. [60]	5G-oriented IoNT	Regarding network lifetime, there was a considerable enhancement. Also, regarding retransmission in packet reception rates, there was a significant augmentation.	Strict key management was deployed by the prevailing security mechanisms; also, they were not apt for a large-scale IoNT paradigm.
R. Senthil, et al. [61]	IoNTconcise with healthcare application	As per the evaluation, encouraging outcomes were depicted by IoNT in handling this disease during the COVID-19 pandemic.	The size was augmented by maximizing the abilities of those devices that make the employment tedious.
Bokang, et al. [62]	IoNT with multimedia design	As per the evaluation, the noted path loss might differ; however, the frequencies of 0.5-1.5 THz were attained for a human skin model with depths of 0.21 mm, 1.23 mm, 1.38 mm, and 3.76 mm.	The model considered only limited opportunities
Fariha, et al. [63]	IoNT with BAN	Analysis showed that the applied energy-efficient cluster-based forwarding scheme in IoNT outperformed the random forwarding scheme	Approach time length was sometimes extended

Table 4: List of Research Problems Obtained for Infrastructural and Security of Iont in Medical Applications

Sl No	Potential Research Problems	Description
1	Weak default passwords (Security) [71]	IoNT device's vulnerability could be enhanced to brute force attack while a password is weak or could be easily estimated. Thus, the data in medical applications could be easily hacked. Presently, 50 % of people have weak passwords.
2	Former infrastructure blocks the medical industry (Infrastructural) [72]	There is a requirement for technology-savvy expertise; also, emerging healthcare organizations aren't essential to commence with former facilities. The IoNT technologies' new improvement toward health care will be hidden if the infrastructure is outdated.



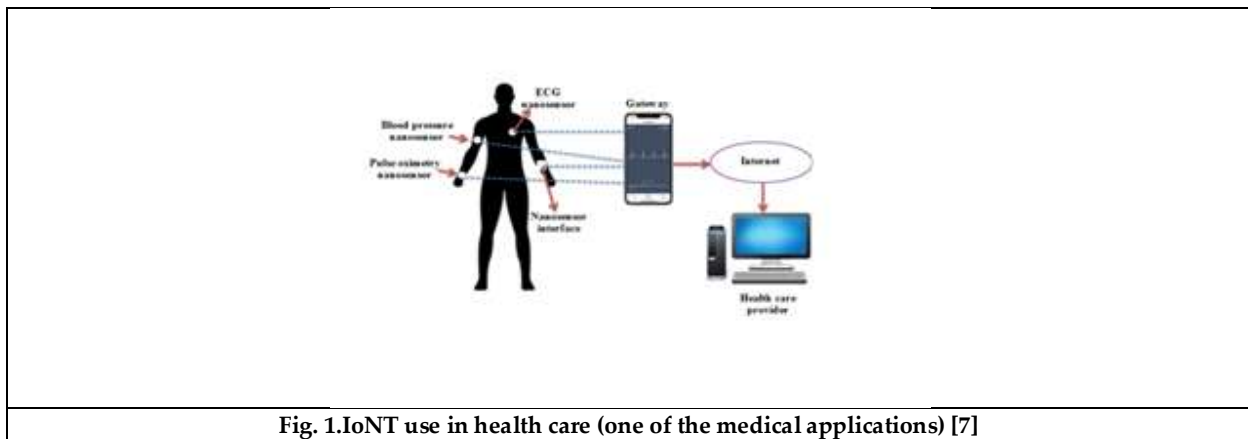


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3	Lack of predicting threats (security) [73]	In some healthcare organizations, there would not be any capabilities for monitoring devices as well as detecting threats. So, it was tedious to identify potential violations at an earlier stage. 22.38 % failed to predict the threats.
4	IoNT presents some overlooked barriers (Infrastructural) [74]	Generally, IoNT devices can't exceed the scheduled time for layoff contrary to websites is a thing that healthcare establishments often overlook.

Table 5: Percentage of Comparison of Research Problems Obtained for Infrastructural and Security of Iont in Medical Applications

Problems	Percentage (%)
WEAK DEFAULT PASSWORDS	50%
LACK OF PREDICTING THREATS	22.38%
USER PRIVACY	26.00%





Coumarin Derivatives as Enoyl Acyl Carrier Reductase Inhibitors in Antitubercular Therapy

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ABSTRACT

Tuberculosis is a worldwide pandemic caused by *Mycobacterium tuberculosis* mainly affecting infected patient's pulmonary system. Enoyl-acyl carrier protein reductase *InhA* plays an essential role in the biosynthesis of fatty acid which is the main content in the *Mycobacterial* cell wall and it possesses the key target for antitubercular drugs. In the present study, different substituted heterocyclic derivatives of coumarin were designed and docked against enoyl reductase (PDB ID: 4TZK). The designed ligands showed significant binding interaction towards the targeted enzyme than the reference ligand nicotinamide adenine dinucleotide. Ligands 1A, 2A and 3A showed high dock scores of -11.77, -11.68 and -11.51 respectively. These ligands can be considered for the further development of novel antitubercular drugs.

Keywords: Coumarin, Enoyl acyl carrier protein, Tuberculosis, docking





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INTRODUCTION

Tuberculosis remains a leading cause of morbidity and mortality in developing countries, including India. According to WHO about 1.6 million people died from tuberculosis in 2021 and the rate is expected to increase 3-fold in the coming years. It is the major cause of death among HIV-infected people. The bacteria bearing several virulence factors including a high content of mycolic acid in their cell wall makes the alveolar macrophages difficult to eliminate and it get multiplies and interferes with the natural defense mechanism of the infected person. Enoyl-acyl carrier protein reductase In hA plays an important role in the biosynthesis of fatty acid which is the main content in the Mycobacterial cell wall and it possesses the key target for antitubercular drugs. InhA catalyzes the NADH-dependent reduction of long chain tran-2-enoyl ACP in typeII fatty acid.[1] There are various effective regimens are available for tuberculosis therapy however, the major issue is the development of antimicrobial resistance and high toxicity due to the prolonged treatment in tb infected patients. This indicates the importance for developing newer potential drug molecules for tuberculosis. Coumarin is a naturally occurring compound found in different plant parts as secondary metabolites. With a fused structure of benzene and pyrone they form a sizable class of significant lactones. The research studies prove that coumarin moiety have a wide variety of possible applications in the field of therapeutics specially in modulators of Anti-tuberculosis because of its distinct structure has a distinctive property that enables its derivatives to easily interact through weak bond interactions with a variety of macromolecules in organisms.[2] In this paper we focus on designing a series of different heterocyclic and aromatic ring substituted coumarin derivatives and evaluate the inhibitory activity of proposed ligands against enoyl acyl reductase by molecular docking studies.

MATERIALS AND METHODS

All the chemical structures of the proposed ligands were designed and the molecular properties were investigated using the tool Chem Sketch (ACD/ChemSketch freeware2022.2). All the structures were viewed on Molegro molecular viewer 2.5. The docking study was carried out using Schrodinger maestro version.

Ligand generation

The structures of different coumarin derivatives comprising heterocyclic rings for docking against the Enoyl reductase enzyme were drawn using Chems sketch. The physicochemical properties of the structures were generated and investigated for Lipinski's rule of five by using Molinspiration. All the molecular structures are viewed and inspected using the Molegro Molecular Viewer for correction, verification, and optimization of structures. Different possible conformations of the proposed ligands were generated using Schrodinger software. The structures of the proposed ligand given in Figure 1, 2 and 3 and the structure details are depicted in Tables 1,2 and 3 respectively.

Protein preparation

The crystal structure of the target protein was downloaded from the PDB (protein data bank). The PDB ID of enoyl reductase was 4TZK. The crystal structure of Mycobacterium tuberculosis enoyl reductase (InhA) complexed with 1-cyclohexyl-N-(3,5-dichlorophenyl)-5-oxopyrrolidine-3-carboxamide and nicotinamide-adenine-dinucleotide as the bound ligand. The R-value of the crystal structure was 0.151 with a resolution of 1.62Å. The targeted protein 4TZK belongs to Mycobacterium tuberculosis H37Rv. The protein was prepared using the Protein Preparation Wizard of Schrodinger Suite. The downloaded protein was energy minimized by adding hydrogen atoms, removing water molecules and verifying the protonation state, especially near the binding site. The proteins were then prepared for docking using the maestro version by adding the missing residues or loops and assigning atomic charges to enoyl reductase.





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RESULTS

All the designed ligands were screened for Lipinski's rule of five and none of the compounds showed any violations. The binding interactions of the proposed ligands with the binding pockets of enoyl reductase were investigated through molecular docking. The predicted binding pockets of enoyl reductase comprise the amino acids ILE 21, ALA 191, GLY 192, PRO 193, ILE 194, MET 147, ASH 148, PHE 149, LEU 218, ILE 215, MET 155, PRO 156, ALA 157, TYR 158, GLY 104, MET 103, ILE202, MET 199. The docking score of the reference nicotinamide adenine dinucleotide was found to be -10.358. The selected ligands showed a better binding interaction on the predicted binding site than the bound ligand and possessed a higher dock score than the same. The values range from -11.71 to -10.44. Table 4 shows the docking score of substituted pyridine ring derivatives of 7,8-dihydroxy coumarin against enoyl reductase. The ligand 1A which is a nitropyridine-substituted chalcone showed the highest dock score of -11.71 with a lower energy conformation. Figure 4 shows the binding interaction of ligand 1A with enoyl reductase. The hydroxy group binds with the PRO 156 through hydrogen bonding interaction and the nitrogen of the pyridine ring interacts with ILE 194 through hydrogen bonding. A pi-pi stacking is seen between the aromatic ring of the coumarin and PHE 149. Ligand 1B shows a docking score of -11.50 due to the interaction of the hydroxy group with PRO 156 and the interaction of pyridine nitrogen with ILE 194. Theobromine atom which is substituted on the pyridine ring, interacts with LYS 165 through halogen bonding. Figure 5 shows the binding interaction of ligand 1B with enoyl reductase. Table 5 shows Docking score of the substituted naphthalene ring derivatives of 7,8-dihydroxycoumarin against enoyl reductase. Ligand 2A showed a dock score of -11.68 due to interaction of hydroxy group with PRO156 through hydrogen bonding. A pi-pi stacking is seen between aromatic ring of coumarin and PHE 149. LYS 165 forms a salt bridge with the substituted SO₂ group. Figure 6 shows binding interaction of ligand 2A with enoyl reductase. Table 6 shows docking score of the substituted benzene ring derivatives of 7,8-dihydroxycoumarin against enoyl reductase. Ligand 3A shows docking score of -11.513 due to the interaction of the hydroxy group with both GLY 192 and ILE 194. Figure 7 shows binding interaction of ligand 3A with enoyl reductase.

DISCUSSION

The docking studies of coumarin comprising different substituted heterocyclic rings were carried out against enoyl reductase (PDB ID: 4TZK). The ligands 1A, 2A and 3A showed greater inhibitory activity against the enoyl reductase enzyme with docking scores of -11.77, -11.68 and -11.51 respectively, as compared to the bound ligand nicotinamide. The hydrogen bonding interactions of the hydroxyl group and the pyridine nitrogen play an important role in binding to the active site. Substituting the coumarin ring with polar groups and aromatic rings results in the formation of molecules with higher activity against enoyl reductase. These ligands can be developed into novel antitubercular molecules through further exploration.

REFERENCES

1. Yan W, Zheng Y, Dou C, Zhang G, Arnaout T, Cheng W. The pathogenic mechanism of Mycobacterium tuberculosis: implication for new drug development. *Mol Biomed* 2022.3(1):48.
2. Hu YQ, Xu Z, Zhang S, Wu X, Ding JW, Lv ZS, Feng LS. Recent developments of coumarin-containing derivatives and their anti-tubercular activity. *Eur J Med Chem* 2017.136:122-130.
3. Kuppaswamy, U. Rajan, R.K. Kumar, A. In-silico and in-vitro analysis of novel substituted benzimidazolyl derivatives for antimycobacterial potentials targeting enoyl acyl carrier protein reductase (InhA). *Future J Pharm Sci* 2022.8:61.
4. Pinzi L, herbet C, Baltas M, Pellati F, Rastelli G. In Silico Repositioning of Cannabigerol as a Novel Inhibitor of the Enoyl Acyl Carrier Protein (ACP) Reductase (InhA). *Molecules* 2019. 24(14):2567.
5. Kawase M, Varu B, Shah A, Motohashi N, Tani S, Saito S, et al. antimicrobial activity of new coumarin derivatives. *Arzneimittelforschung* 2001.51(1):67-71.





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- Muratovic S, Duric K, Veljovic E, Osmanovic A, Softic D, Zavrtnik. Synthesis of biscoumarin derivatives as antimicrobial agents. *Asian Journal of Pharmaceutical and Clinical Research* 2013.6(3):131–134.
- Singh K, Pandey N, Ahmad F, Upadhyay TK, Islam MH, Alshammari N, Saeed M, Al Keridis L A, Sharma R. Identification of Novel Inhibitor of Enoyl Acyl Carrier Protein Reductase (InhA) Enzyme in *Mycobacterium tuberculosis* from Plant Derived Metabolites: An In Silico Study. *Antibiotics (Basel)* 2022.11(8):1038.
- Brahmbhatt DI, Patel A K, Patel N H, Patel M A. Synthesis, characterization and antimicrobial activity of some 4-aryl-2,6-di(coumarin-3-yl)pyridines. *Arkivoc*.2010(11):28–38.
- Eltschkner S, Kehrein J, Le TA, Davoodi S, Merget B, Basak S, Weinrich JD, Schiebel J, Tonge PJ, Engels B, Sotriffer C, Kisker C. A Long Residence Time Enoyl- Reductase Inhibitor Explores an Extended Binding Region with Isoenzyme-Dependent Tautomer Adaptation and Differential Substrate-Binding Loop Closure. *ACS Infect Dis* 2021.7(4):746-758.
- Wadhwa P, Saha D, Sharma A. Combined 3D QSAR and Molecular Docking Study for Identification of Diverse Natural Products as Potent PfENR Inhibitors. *Curr Comput Aided Drug Des* 2015.11(3):245-57.
- Baptista R, Bhowmick S, Shen J, Mur LAJ. Molecular Docking Suggests the Targets of Anti-Mycobacterial Natural Products. *Molecules* 2021.18;26(2):475.
- Clair Baldock, Svetlana E. Sedelnikova, Patrick J. Baker, Antoine R. Stuitje, Antoni R. Slabas et al. A Mechanism of Drug Action Revealed by Structural Studies of Enoyl Reductase. *Science*.1996; 274:2107-2110.
- Moustafa G, Khalaf H, Naglah A, Al-Wasidi A, Al-Jafshar N, Awad H. The Synthesis of Molecular Docking Studies, In Vitro Antimicrobial and Antifungal Activities of Novel Dipeptide Derivatives Based on N-(2-(2-Hydrazino-2-oxoethylamino)-2-oxoethyl)-nicotinamide. *Molecules*.2018; 23(4):761.
- Mingliang Zhang, Huaidong Zhang, Qin Li, Yangle Gao, Lijun Guo, Liu He, Shanshan Zang, Xing Guo, Jianzhong Huang, and Li Li. Structural Insights into the *Trans*-Acting Enoyl Reductase in the Biosynthesis of Long-Chain Polyunsaturated Fatty Acids in *Shewanella piezotolerans*. *Journal of Agricultural and Food Chemistry*.2021; 69(7): 2316-2324.
- Wang YR, Fang Q, Hu TY, Liu Y. Spectroscopic and Molecular Docking Study on Specific Binding and Inhibition of Isoniazid to Human Serum Albumin and Catalase. *Guang Pu Xue Yu Guang Pu Fen Xi*.2016; 36(11):3789-95.

Table 1: Ligand Structure Details

LIGAND	R	R ₁	IUPAC NAME
1A	H	NO ₂	5-(7,8-dihydroxy-2-oxo-2H-1-benzopyran-3-yl)pyridin-3-yl nitrite
1B	H	Br	3-(5-bromopyridin-3-yl)-7,8-dihydroxy-3,4-dihydro-2H-1-benzopyran-2-one
1C	NH ₂	H	3-(6-aminopyridin-3-yl)-7,8-dihydroxy-2H-1-benzopyran-2-one
1D	H	I	7,8-dihydroxy-3-(5-iodopyridin-3-yl)-2H-1-benzopyran-2-one
1E	H	OH	7,8-dihydroxy-3-(5-hydroxypyridin-3-yl)-2H-1-benzopyran-2-one
1F	CN	H	6-(7,8-dihydroxy-2-oxo-2H-1-benzopyran-3-yl)-1,6-dihydropyridine-2-carbonitrile

Table 2: Ligand Structure Details

LIGAND	R	R ₁	IUPACNAME
2A	HSO ₃	H	6-(7,8-dihydroxy-2-oxo-2H-1-benzopyran-3-yl)naphthalene-1-sulfonic acid
2B	H	OH	7,8-dihydroxy-3-(6-hydroxynaphthalen-2-yl)-2H-1-benzopyran-2-one
2C	OH	OH	3-(5-acetylnaphthalen-2-yl)-7,8-dihydroxy-2H-1-benzopyran-2-one
2D	H	F	3-(6-fluoronaphthalen-2-yl)-7,8-dihydroxy-2H-1-benzopyran-2-one
2E	H	I	7,8-dihydroxy-3-(6-iodonaphthalen-2-yl)-2H-1-benzopyran-2-one
2F	Br	H	3-(5-bromonaphthalen-2-yl)-7,8-dihydroxy-2H-1-benzopyran-2-one





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2G	NO ₂	H	7,8-dihydroxy-3-(5-nitronaphthalen-2-yl)-2H-1-benzopyran-2-one
2H	H	Cl	3-(6-chloronaphthalen-2-yl)-7,8-dihydroxy-2H-1-benzopyran-2-one
2I	H	H	7,8-dihydroxy-3-(naphthalen-2-yl)-2H-1-benzopyran-2-one
2J	H	COCH ₃	3-(6-acetylnaphthalen-2-yl)-7,8-dihydroxy-2H-1-benzopyran-2-one

Table 3: Ligand Structure Details

ligand	R	R1	IUPACNAME
3A	H	Br	3-(3-bromophenyl)-7,8-dihydroxy-2H-1-benzopyran-2-one
3B	H	COC ₆ H ₅	3-(4-benzoylphenyl)-7,8-dihydroxy-2H-1-benzopyran-2-one
3C	CL	H	3-(2-chlorophenyl)-7,8-dihydroxy-2H-1-benzopyran-2-one

Table 4: Docking Score of Substituted Pyridine Ring Derivatives of 7,8-Dihydroxy Coumarin Against Enoyl Reductase.

LIGAND	DOCKSCORE
1A	-11.77
1B	-11.50
1C	-11.17
1D	-11.15
1E	-10.98
1F	-10.47
Nicotinamide adenine dinucleotide	-10.35

Table 5: Docking Score of the Substituted Naphthalene Ring Derivatives of 7,8-Dihydroxycoumarin Against Enoyl Reductase.

LIGAND	DOCKSCORE
2A	-11.68
2B	-11.43
2C	-11.42
2D	-10.93
2E	-10.83
2F	-10.74
2G	-10.68
2H	-10.59
2I	-10.56
2J	-10.831

Table 6: Docking Score of the Substituted Benzene Ring Derivatives of 7,8-Dihydroxy Coumarin Against Enoyl Reductase.

LIGAND	DOCKSCORE
3A	-11.51
3B	-10.92
3C	-10.86





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<p>Fig 1: General structure of docked ligand (1A-1F)</p>	<p>Fig 2: General structure of the docked ligand (2A-2J)</p>
<p>Fig 3: General structure of the docked ligand (3A-3C)</p>	<p>Fig.4: Binding interaction of ligand 1A with enoyl reductase</p>
<p>Fig.5: Binding interaction of the ligand 1B with enoyl reductase</p>	<p>Fig. 6: shows binding interaction of ligand 2A with enoyl reductase</p>
<p>Fig.7: Binding interaction of ligand 3A with enoyl reductase</p>	





Liquid Waste Treatment using Organic Coagulating Agents

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ABSTRACT

The most detrimental to the environment and human health are sewage pollution. The high concentration of pollutants in sewage makes its treatment and disposal seem like a major problem for a number of sectors. The most efficient method for removing pollutants appears to be coagulation-flocculation. Therefore, I want to use natural coagulants like *Cicer arietinum* (powder made from chickpeas) and *Moringa olifera* (powder made from moringa seeds) to treat sewage waste water in my project. In this project, an exploratory study was conducted to see whether natural coagulants could be used to treat wastewater. Sedimentation will be used to treat the sewage wastewater. To assess the effectiveness of the removal of major pollutants involved in the waste water treatment process, such as pH, turbidity, sulphates, chlorides, total solids, total suspended solids (TSS), total dissolved solids (TDS), acidity, alkalinity, biological oxygen demand (BOD), and chemical oxygen demand (COD), the physico-chemical parameters of the waste water are measured both before and after the treatment. This technology is useful for quickly, cheaply, and easily purifying turbid water that has been contaminated.

Keywords: COD, BOD, Turbidity, coagulation, Chromium Removal.

INTRODUCTION

Sewage is the main source of water pollution nowadays there is no proper maintenance of sewage so it pollutes the fresh water source. The intention of wastewater treatment is to eliminate the pollutants from water so the treated water can meet the satisfactory quality standards. The type of treatment required which depends on the nature and quality of both sewage and source of disposal. Turbidity in wastewater is due to suspended matter, such as clay, silt, and finely divided organic and inorganic matter, soluble colored organic matters, turbidity water has cloudy look



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and not attractive. High levels of pollutants in river water causes an increase in BIOLOGICAL OXYGEN DEMAND (BOD₅), CHEMICAL OXYGEN DEMAND (COD), TOTAL DISSOLVED SOLIDS (TDS), total suspended solids (TSS), and hence make such water unsuitable for drinking. It is found all rivers are polluted in most of the stretches by some industry or other irrigation and aquatic life. Coagulant techniques for wastewater treatment have become popular in recent years due to their efficiency in the in the removal of pollutants that are to be removed by biological methods. The discharge of non-biodegradable physicochemical parameters like p^H and like turbidity into water stream is hazardous because the consumption of polluted water causes various health problems.

Turbidity goes on increases sewage becomes stronger. Due to the lack of appropriate wastewater treatment systems in these rural or underdeveloped societies, the best instant option is to use simple and cost-effective point of point technologies such as coagulation. Activated Sludge Process, Oxidation Ponds, Aerated Lagoons and Trickling Filters are the conventional treatment process in India.

This treatment process basically requires land and Energy which increases overall cost of treatment process. The naturally available coagulants were used to reduce the treatment cost.

HISTORY OF LIQUID WASTE

Sewage (or domestic wastewater or municipal wastewater) is a type of wastewater that is produced by a community of people. It is characterized by volume orate of flow, physical condition, chemical and toxic constituents, and its bacteriologic status (which organisms it contains and in what quantities). It consists mostly of grey water (from sinks, tubs, showers, dishwashers, and clothes washers), black water (the water used to flush toilets, combined with the human waste that it flushes away); soaps and detergents; and toilet paper (less so in regions where bidets are widely used instead of paper).

Sewage usually travels from a building's plumbing either into a sewer, which will carry it elsewhere, or into an onsite sewage facility (of which there are many kinds). Whether it is combined with surface runoff in the sewer depends on the sewer design (sanitary sewer or combined sewer). The reality is that most wastewater produced globally remains untreated causing widespread water pollution especially in low-income countries. A global estimate by UNDP and UN-Habitat is that 90% of all wastewater generated is released into the environment untreated. In many developing countries the bulk of domestic and industrial wastewater is discharged without any treatment.

NATURAL WASTEWATER TREATMENT SYSTEM

Adapting conventional chemical treatments have now caused growing negative impacts on the land and groundwater systems. Natural wastewater treatment systems are thus used all over the world for the treatment of wastewater from industries, house hold and agriculture. Natural treatment systems are those having minimal dependence on mechanical elements to support the wastewater treatment process. Instead, the systems use plants and bacteria to breakdown and neutralize pollutants in wastewater. They minimize the use of chemicals and require little energy to operate.

It is important to use natural wastewater treatment systems considering their use of treated water. This is needed above all in arid regions. Natural wastewater treatment systems are simple, cost-effective and efficient methods to purify the growing amount of wastewater produced by our society. They can be applied as secondary or tertiary purification treatment, allowing there removal of most of the bacteria, microorganism and the destruction of the organic matter. The extreme simplicity in building, operation and maintenance makes these systems highly competitive with the conventional treatment methods.



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EXPERIMENTAL METHODOLOGY

The hierarchy of work to be done to assess the treatment of SEWEGE effluent using natural coagulation is shown in the following flow chart 2.1.

GUIDANCE FOR HANDLING SEWAGE WASTEWATER

Humans who handle the sewage may be at increased risk of becoming ill from waterborne diseases. To reduce this risk and protect against illness, such as diarrhea, vomiting, fever and breathing problems. The following guidance should be followed; They are,

- Use waterproof gloves to prevent cuts and contact with sewage.
- Wash hands with soap and water immediately after handling wastewater
- Avoid touching face, mouth, eyes, open sores and cuts while handling sewage.
- After handling sewage wastewater, wash your hands with soap and water before eating or drinking.
- Do not smoke or chew tobacco or gum while handling sewage.
- Keep open sores, cuts, and wounds covered with clean, dry bandages.
- Gently flush eyes with safe water.
- Remove rubber boots and work clothes before leaving the worksite.

ANALYSIS OF SEWAGE EFFLUENT

The Sewage effluent is analysed to determine various parameters like pH, turbidity, Total suspended solids (TSS), Chemical oxygen demand (COD), Biological Oxygen Demand (BOD), Sulphides (as S), Total Chromium (Cr⁺), Hexavalent Chromium (Cr⁶⁺) at each stage of the treatment system.

QUANTITATIVE ANALYSIS OF RAW EFFLUENT AT INITIAL STAGE

Before any treatment, a quantitative examination of the raw sewage effluent is conducted, and the average of the results is used to determine the baseline values of various effluent characteristics. Table 1 depicts the results obtained from the quantitative analysis of raw effluent.

COAGULATION AND FLOCCULATION OF WASTE WATER TREATMENT

Coagulation and flocculation are an essential part of drinking water treatment as well as wastewater treatment. This article provides an overview of the processes and looks at the latest thinking. Material for this article was largely taken from reference.

Moringa oleifera

The most widely cultivated species of a monogeneric family, the Moringaceae mostly found in the sub-Himalayan tracts of India, Pakistan, Bangladesh and Afghanistan. This rapidly-growing tree (also known as the horseradish tree, drumstick tree, benzolive tree or Ben oil tree), is now widely cultivated in many locations in the tropics. It is commonly referred to as the miracle tree because of the multipurpose uses of the plant parts. Seed kernels contain a significant amount of oil that is commercially known as Ben oil or Behen oil which is high in tocopherols.

Earlier researches have revealed its ability to treat high, medium and low turbidity water. It can also be used as a softening agent as well as been as a dewatering agent hence its importance cannot be overemphasized in water treatment. When this compared with conventional chemical coagulants, it has the following advantages such as cost effectiveness, availability, biodegradable sludge, eco- friendly, low sludge volume, it does not produce harmful by-products, it is easily handled as it is not corrosive, and it does not affect pH of water. Seed in different extracted and purified forms has proven to be effective at removing suspended material, soften hard waters, removal of turbidity, Chemical Oxygen Demand (COD), color and other organic pollutant.



**Muthuraman et al.,*****Cicer arietinum***

The most widely cultivated species. Chickpea is a key ingredient in hummus and chana masala, and it can be ground into a flour to make falafel. It is also used in salads, soups and stews, curry and other meal products like channa. The chickpea is important in Indian, Mediterranean and Middle Eastern cuisine. The plant grows to 20–50 cm (8–20 in) high and has small, feathery leaves on either side of the stem. Chickpeas are a type of pulse, with one seedpod containing two or three peas. It has white flowers with blue, violet, or pink veins. When this compared with conventional chemical coagulants, it has the following advantages such as cost effectiveness, availability, biodegradable sludge, eco-friendly, low sludge volume, it does not produce harmful by-products, it is easily handled as it is not corrosive, and it does not affect pH of water.

FINAL ANALYSIS OF WASTEWATER

The treated effluent is quantitatively analysed, and an average is calculated and as shown in table 2.

CONCLUSION

The features of the sewage waste water and an analysis of the different parameters. Since the goal of sustainable environmental technology is to improve the quality of life for underprivileged populations, the use of natural coagulants derived from plant-based sources is an important advancement. However, the loss of large agro-based plant plantations has restricted the use of natural coagulants. Technically speaking, these naturally occurring coagulants are quite effective at treating low-turbidity fluids; however, they might not be practical for treating wastewaters with extremely high pH levels. Therefore, it is always advisable for those who treat water to carefully choose the best natural coagulants and customise them for certain uses. Better results are obtained from the treated waste water when *Moringa oleifera* is used as a natural coagulant. Finding the ideal coagulant dosage and employing natural coagulant in proportions yields the greatest outcomes.

REFERENCES

1. N. Hilal, G. Busca, F. Talens-Alesson, and B. P. Atkin, "Treatment of waste coolants by coagulation and membrane filtration," *Chemical Engineering and Processing*, vol. 43, no. 7, pp. 811–821, 2004.
2. M. Kobya, C. Ciftci, M. Bayramoglu, and M. T. Sensoy, "Study on the treatment of waste metal cutting fluids using electrocoagulation," *Separation and Purification Technology*, vol. 60, no.3, pp. 285–291, 2008.
3. C. Chenga, D. Phippsa, R. M. Alkhaddar, and R.M., "Treatment of spent metalworking fluids," *Water Research*, vol. 39, no. 17, pp. 4051–4063, 2005.
4. M. Sokovic and K. Mijanovic, "Ecological aspects of the cutting fluids and its influence on quantifiable parameters of the cutting processes," *Journal of Materials Processing Technology*, vol. 109, no. 1-2, pp. 181–189, 2001.
5. M. Greeley and N. Rajagopalan, "Impact of environmental contaminants on machining properties of metalworking fluids," *Tribology International*, vol. 37, no. 4, pp. 327–332, 2004.
6. S. Rios, C. Pazos, and J. Coca, "Destabilization of cutting oil emulsions using inorganic salts as coagulants," *Colloids and Surfaces A*, vol. 138, no. 2-3, pp. 383–389, 1998.





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Table 1. Raw Effluent Analysis

S.No.	Parameter	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Average
1	Turbidity (mg/l)	15.4	15.5	16	15.9	16.2	15.8	15.3	15.73
2	pH	12.9	13.4	13.2	13.1	12.8	13.2	13.1	13.14
3	TSS (mg/l)	681	682	673	674	685	674	687	679.43
4	BOD (mg/l)	595	598	585	593	591	587	588	591
5	COD (mg/l)	2548	2549	2551	2549	2553	2548	2543	2548
6	Sulphides (mg/l)	35	39	35	39	37	33	34	36
7	Total Chromium (Cr ⁺) (mg/l)	25	26	29	28	28	26	27	27
8	Hexavalent Chromium (as Cr ⁶⁺) (mg/l)	15.6	15.8	17	15.9	16.4	15.8	15.7	16.02

Table 2. Treated Effluent Analysis

S.No.	Parameter	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Average
1	Ph	6.6	6.75	7	6.4	6.5	6.7	6.6	6.65
2	Turbidity (mg/l)	0.7	0.9	0.8	1	0.8	0.8	1	0.85
3	TSS (mg/l)	26	27	24	27	26	27	25	26
4	COD (mg/l)	37	41	38	42	38	40	37	39
5	BOD (mg/l)	13	14	13	11	13	12	15	13
6	Sulphides (mg/l)	1.47	1.52	1.56	1.48	1.51	1.49	1.5	1.5
7	Total Chromium (Cr ⁺) (mg/l)	1.54	1.53	1.67	1.55	1.59	1.63	1.61	1.59
8	Hexavalent Chromium (as Cr ⁶⁺) (mg/l)	0.08	0.09	0.09	0.08	0.07	0.06	0.08	0.08

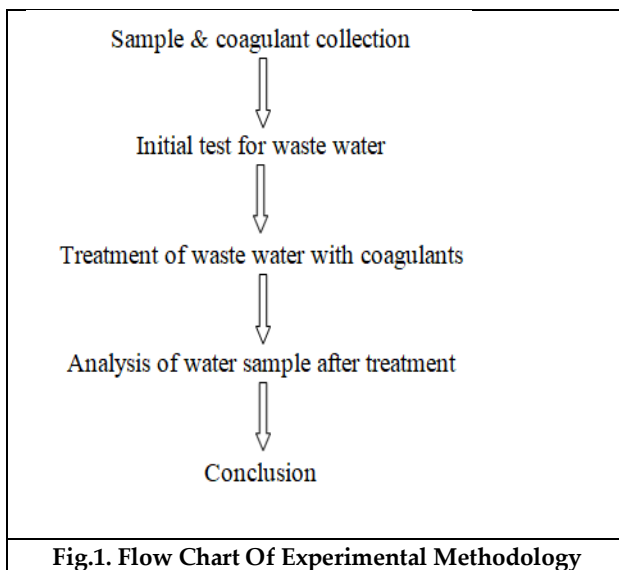


Fig.1. Flow Chart Of Experimental Methodology

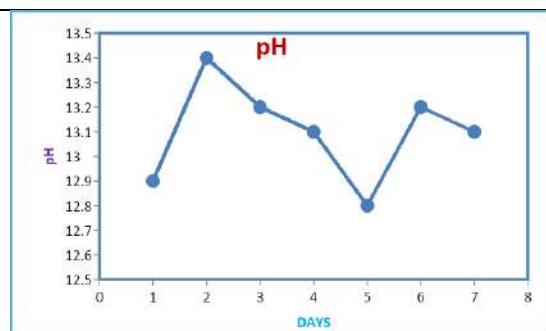
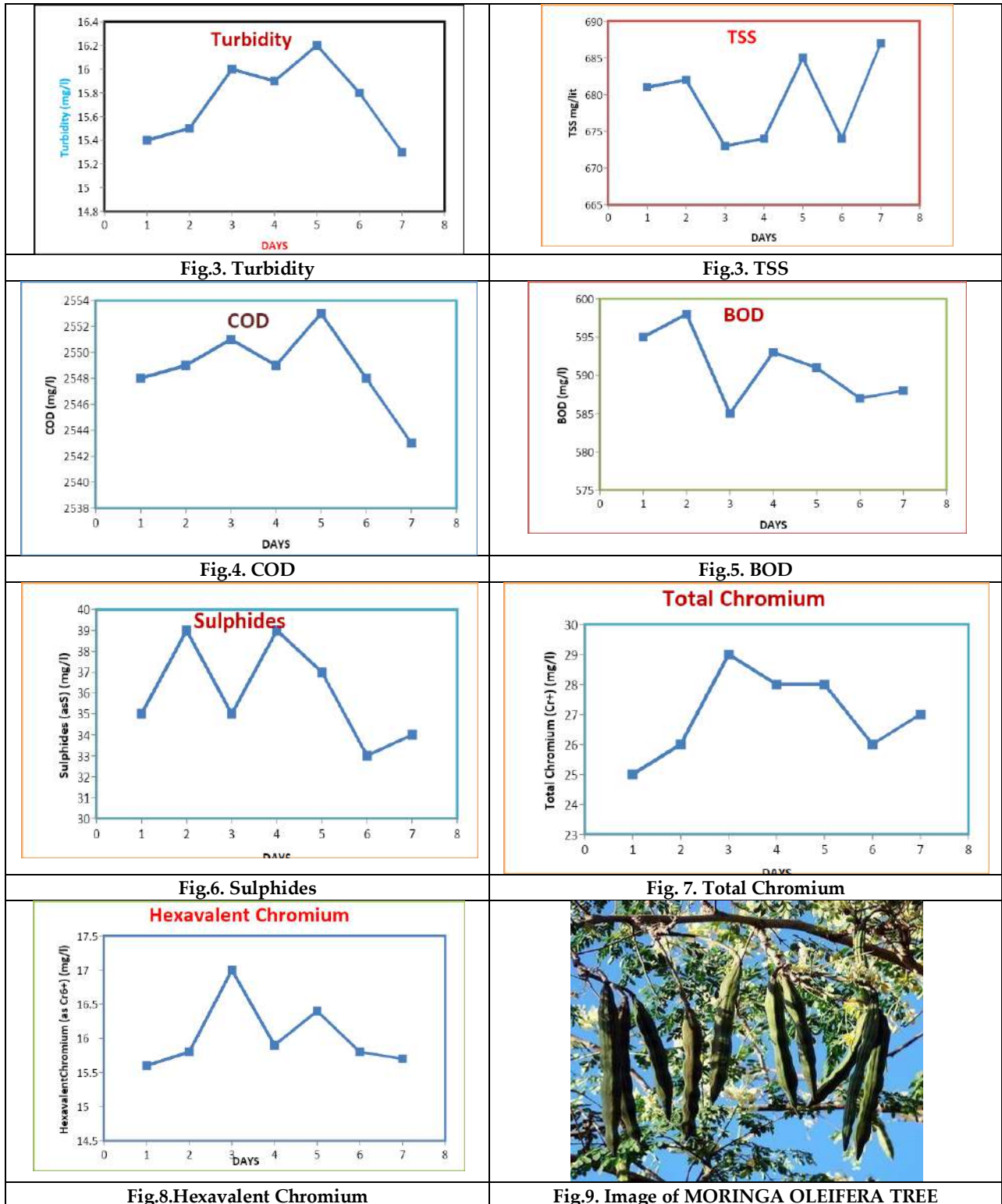


Fig.2.pH



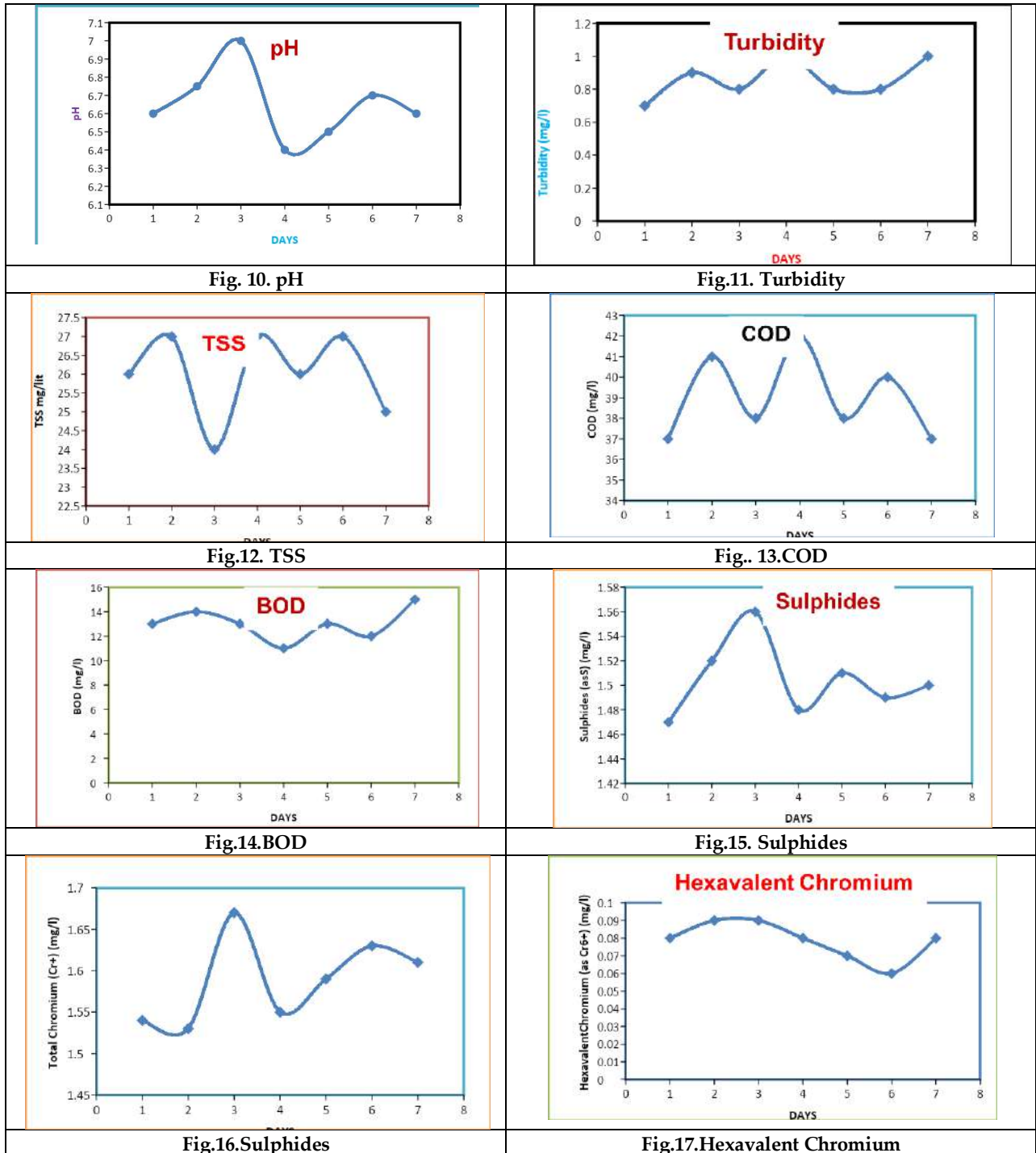


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Total Directed Graph

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ABSTRACT

In this paper, we define Total directed graph $T(D)$ of a directed graph D and we establish bounds for sum of in-degree (out-degree) of $T(D)$ with sum of in-degree (out-degree) of D and we investigate the various parameters of $T(D)$.

Keywords: Total graph, Directed graph, Total directed graph.

INTRODUCTION

Ancy K.Joseph,T.B.Athul obtaining a total graph from any given graph is a popular area of research in graph theory [3][4]. Total graph of a graph G , denoted by $T(G)$ is a graph whose vertices are represented by each vertex and each edge of G . There is an edge between two vertices in $T(G)$ if and only if there is edge-edge adjacency or edge-vertex incidence or vertex-vertex adjacency in G . The structural properties of total graphs are investigated in [2][7][8]. Let $D = (V, A)$ be a digraph, For any vertex $u \in V$, the sets $O(u) = \{v/(u, v) \in A\}$ and $I(u) = \{v/(v, u) \in A\}$ are called outset and inset of u . The indegree and outdegree of u are defined by $d_i(u) = |I(u)|$ and $d_o(u) = |O(u)|$. The minimum in-degree, minimum out-degree, maximum in-degree, maximum out-degree of D are denoted by $\delta^-, \delta^+, \Delta^-$ and Δ^+ respectively [5]. The various bounds of digraphs is now well studied in graph theory and the literature on this subject has been surveyed and detailed in the books by Choudam[1] and Haynes, Hedetniemi, Slater. The study of the total graph and directed graph motivated us to introduce the Total directed graphs $T(D)$ and to investigate its bounds and various parameters of $T(D)$.





PRELIMINARIES

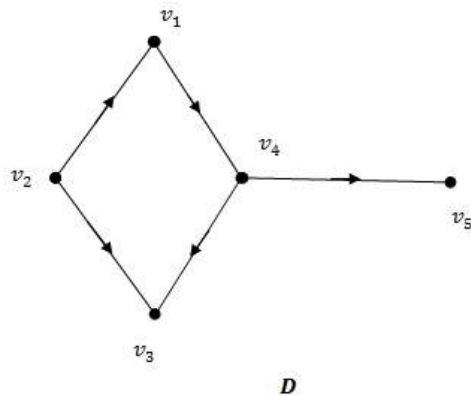
Definition 1.1:

The **total graph** $T(G)$ of G is the graph whose vertex set is $V(G) \cup E(G)$ and two vertices are adjacent in $T(G)$ whenever they are adjacent (or) incident in G .

Definition 1.2 :

A **directed graph** D is an ordered pair (V, A) where V is a non-empty finite set and A is a subset of $\{(u, v) \in V \times V / u \neq v\}$. The elements of V are called vertices and those of A are called arcs (or) directed edges. A (p, q) - digraph refers to a digraph with p vertices and q arcs.

Example

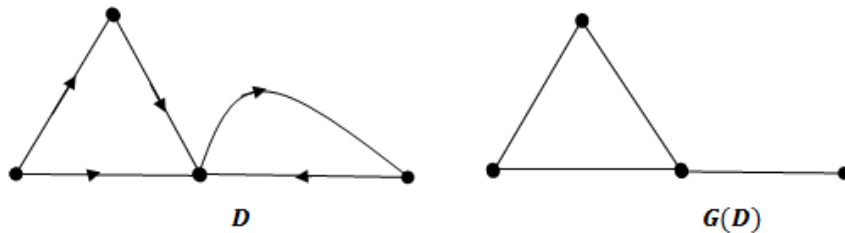


Let $V = \{v_1, v_2, v_3, v_4, v_5\}$ and $A = \{(v_2, v_1), (v_1, v_4), (v_4, v_3), (v_2, v_3), (v_4, v_5)\}$ then (V, A) is a digraph with 5 vertices and 5 arcs.

Definition 1.3:

The **underlying graph** G of a directed graph $D = (V, A)$ has a vertex set V and the edge set $E = \{(u, v) : (u, v) \text{ or } (v, u) \in A\}$ and it is denoted by $G(D)$.

Example



Definition 1.4

A directed walk W is called a directed path if all the vertices in W (and hence arcs) are distinct. The directed path with n vertices is denoted by \vec{P}_n .

Definition 1.5

A closed directed walk from u to v is a directed cycle if all its vertices are distinct except that $u = v$. The directed cycle with n vertices is denoted by \vec{C}_n .





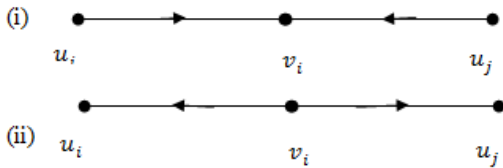
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Total directed graphs

Definition 2.1

Two edges are said to be Anti directed if the adjacent edges are not having same direction.

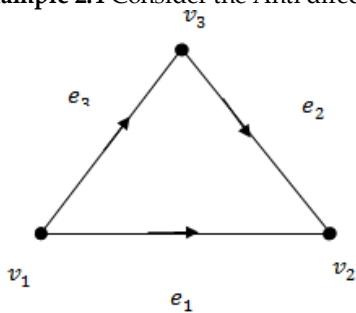
Example 2.2



Definition 2.3

A closed anti directed walk from u to v is a Anti directed cycle if all its vertices are distinct except that $u = v$. The Anti directed cycle with n vertices is denoted by \vec{C}_n .

Example 2.4 Consider the Anti directed cycle \vec{C}_3 with 3 vertices.

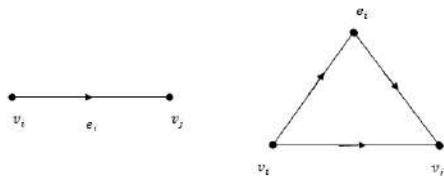


Definition 2.5

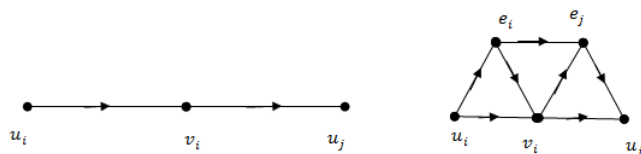
The **Total directed graph** $T(D)$ of a digraph D is defined as follows :

- (i) Consider $T(G(D))$ total graph of underlying graph.
- (ii) We give directions to each edge in $E(T(G(D)))$ as follows.

Case 1: If $e_i = (v_i, v_j) \in A(D)$, Then $(v_i, e_i), (e_i, v_j), (v_i, v_j) \in A(T(D))$.



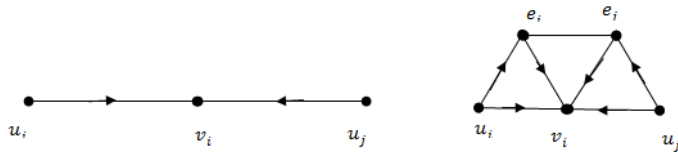
Case 2: If $e_i = (u_i, v_i), e_j = (v_i, u_j) \in A(D)$, Then $(u_i, v_i), (v_i, u_j), (u_i, e_i), (e_i, v_i), (v_i, e_j), (e_j, u_j), (e_i, e_j) \in A(T(D))$



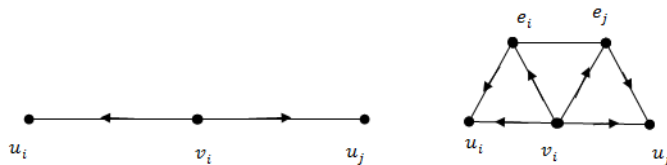


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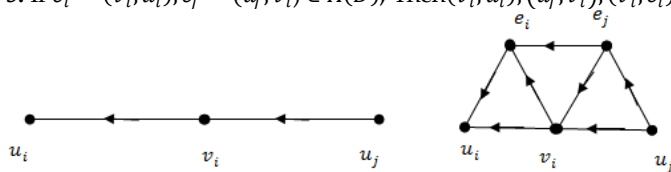
Case 3: If $e_i = (u_i, v_i), e_j = (u_j, v_i) \in A(D)$, Then $(u_i, v_i), (u_j, v_i), (u_i, e_i), (e_i, v_i), (e_j, v_i), (u_j, e_j), (e_i, e_j), (e_j, e_i) \in A(T(D))$



Case 4: If $e_i = (v_i, u_i), e_j = (v_i, u_j) \in A(D)$, Then $(v_i, u_i), (v_i, u_j), (e_i, u_i), (v_i, e_i), (v_i, e_j), (e_j, u_j), (e_i, e_j), (e_j, e_i) \in A(T(D))$



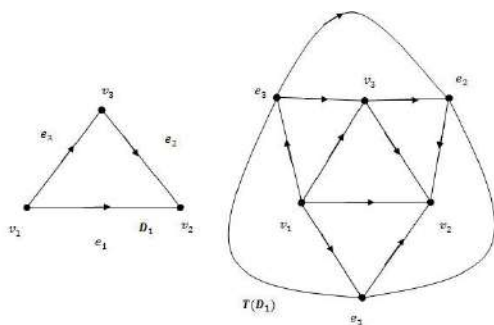
Case 5: If $e_i = (v_i, u_i), e_j = (u_j, v_i) \in A(D)$, Then $(v_i, u_i), (u_j, v_i), (v_i, e_i), (e_i, u_i), (u_j, e_j), (e_j, v_i), (e_j, e_i) \in A(T(D))$



If (u_i, v_j) and $(v_j, u_i) \in A(D)$, then we write as $\bullet \xrightarrow{\hspace{1cm}} \bullet$ instead of $\bullet \xleftarrow{\hspace{1cm}} \bullet$
 $u_i \qquad v_j \qquad u_i \qquad v_j$

Example 2.6

(i) Consider the directed graph with 3 vertices.

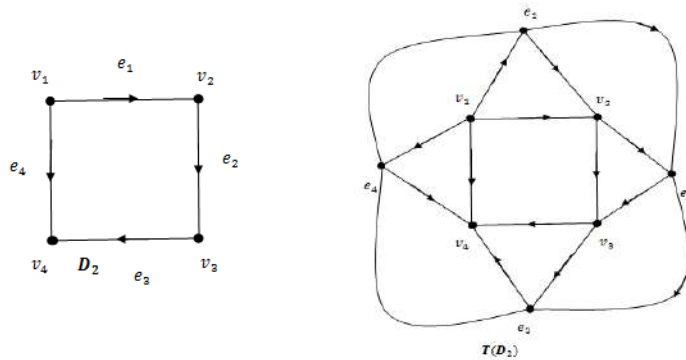


(ii) Consider the directed graph with 4 vertices .





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Observations 2.7

- (i) Each directed edge of D can be developed as Anti directed cycle on 3 vertices in $T(D)$.
- (ii) If the minimum in-degree (out-degree) of a vertex v in D is zero, then the minimum in-degree (out-degree) of a vertex v in $T(D)$ is always zero.

Theorem 2.8

The in-degree (out-degree) of a vertex v in $T(D)$ is twice the in-degree (out-degree) of a vertex v in D .
 (i.e) $2 d^D_i(v) = d^{T(D)}_i(v)$

Proof

Let $T(D)$ be the total directed graph of D . We have to prove that a vertex $v \in T(D)$ having in-degree is twice the in-degree of a vertex v in D . **By observation 2.7-(i)**, each directed edge of D can be embedded a Anti directed cycles with 3 vertices in $T(D)$. We know that either \vec{C}_3 or Anti directed cycles having two incident edges of each vertex and directions of that edges in $T(D)$ assigned from our definition . Hence, the in-degree (out-degree) of a vertex v in $T(D)$ is twice the in-degree of a vertex v in D .

Theorem 2.9

In total directed graph of a directed cycles $\Delta^+(T(D)) = \delta^+(T(D)) = \Delta^-(T(D)) = \delta^-(T(D)) = 2$.

Proof

Let $T(D)$ be a total directed graph of a directed cycles. A directed cycle is a non-empty directed trail in which only the starting and ending vertices are equal and we already know that each vertex v of directed cycles having same in-degree and out-degree which is one . **By observation 2.7-(i)**, each edge of D can be embedded a Anti directed cycles with 3 vertices and we assign a directions to the incident arcs of D in $T(D)$ by using our definition . **By theorem 2.8**, the in-degree (out-degree) of a vertex v in $T(D)$ is twice the in-degree (out-degree) of a vertex v in D . Hence, each vertex of total directed graph of a directed cycles having $\Delta^+(T(D)) = \delta^+(T(D)) = \Delta^-(T(D)) = \delta^-(T(D)) = 2$.

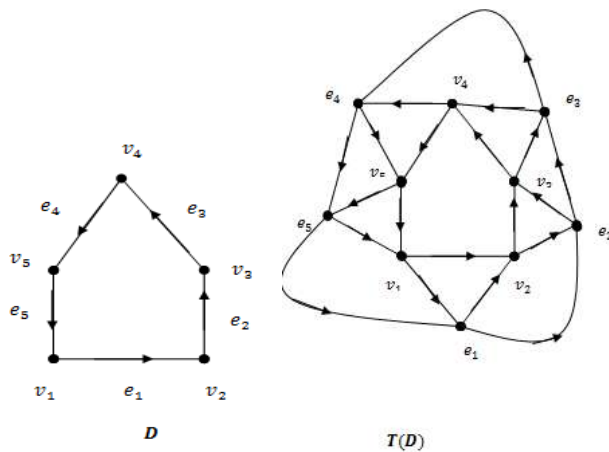
Example 2.10

Consider the directed cycle with 5 vertices and the total directed graph of a directed cycle is shown below.





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From the above figure, all the vertices $v_1, v_2, v_3, v_4, v_5, e_1, e_2, e_3, e_4, e_5$ having maximum in-degree $\Delta^-(T(D))$ and maximum out-degree $\Delta^+(T(D))$, minimum in-degree $\delta^-(T(D))$, minimum out-degree $\delta^+(T(D))$ is two.

Theorem 2.11

In $T(D)$, all the vertices having minimum in-degree(out-degree) and maximum in-degree(out-degree) is always even.

Proof

Let D be a directed graph and $T(D)$ be the total directed graph. **By Observation 2.7-(i)**, Each edge of D can be embedded a Anti directed cycles with 3 vertices in $T(D)$. We already know that each vertex v having two incident edges in directed or undirected cycles . **By Theorem 2.8**, Each vertex v of $T(D)$ having either in-degree (out-degree) is twice the in-degree (out-degree) of a vertex v in D . Therefore, the degree of a vertex v in $T(D)$ having minimum in-degree and maximum in-degree is always even.

Theorem 2.12

The total directed graph $T(D)$ has no trees.

Proof

Let $T(D)$ be a total directed graph of a directed graph D . **By Observation 2.7-(i)**, each directed edge in D can be embedded a Anti directed cycles with 3 vertices. Therefore, every directed edge of D can be embedded a cycle with 3 vertices. Then, $T(D)$ having no vertex of in-degree or out-degree one. Hence, the total directed graph has no trees.

Theorem 2.13

In total directed graph of a directed path $\Delta^+(T(D)) = \Delta^-(T(D)) = 2$ and $\delta^+(T(D)) = \delta^-(T(D)) = 0$.

Proof

Let $T(D)$ be the total directed graph of a directed path. We know that a starting vertex v of a directed path having zero in-degree and ending vertex of a path having zero out-degree and the maximum in-degree and maximum out-degree of directed path is one . **By observation 2.7-(i)**, each edge of D can be embedded a Anti directed cycles with 3 vertices. **By theorem 2.8**, and definition of $T(D)$, the in-degree or out-degree of a vertex v in $T(D)$ is twice the in-degree or out-degree of a vertex v in D . If the minimum in-degree (out-degree) of a vertex v of D is zero, then the minimum in-degree (out-degree) of a vertex v in $T(D)$ is always zero. If the maximum in-degree(out-degree) of a vertex v in D is one, then the maximum in-degree (out-degree) of a vertex v in $T(D)$ is two. Therefore, the total



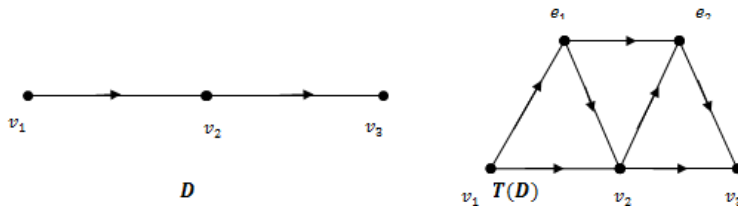


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directed graph of a directed path having maximum in-degree and out-degree is two and minimum in-degree and out-degree is zero.

Example 2.14

Consider the directed path with 3 vertices. A total directed graph of a directed path is shown below.



From the above figure, all the vertices \$v_1, v_2, v_3, e_1, e_2\$ having maximum out-degree \$\Delta^+(T(D))\$, maximum in-degree \$\Delta^-(T(D))\$ is two and minimum out-degree \$\delta^+(T(D))\$, minimum in-degree \$\delta^-(T(D))\$ is zero.

Theorem 2.15

The total directed graph of a directed cycle is 2 – regular.

Proof

Let \$D\$ be a directed cycle \$\vec{C}_n\$ and \$T(D)\$ be a total directed graph of a directed cycle. Here we have to prove that the total directed graph of a directed cycle is 2 – regular. **By theorem 2.9**, A total directed graph of a directed cycle having \$\Delta^+(T(D)) = \Delta^-(T(D)) = \delta^+(T(D)) = \delta^-(T(D)) = 2\$. We know that each vertex having in-degree and out-degree is \$k\$, then the graph is called \$k\$ – regular. Hence, the total directed graph of a directed cycle is 2 – regular.

Theorem 2.16

The sum of in-degree (out-degree) of \$v\$ in \$T(D)\$ is less than or equal to four times the sum of in-degree (out-degree) of \$v\$ in \$D\$. (i.e) \$\sum d^{T(D)}_i(v) \le 4 \sum d^D_i(v)\$.

Proof

Let \$D\$ be the directed graph and \$T(D)\$ be the total directed graph of \$D\$. **By observation 2.7-(i)**, each directed edge of \$D\$ can be embedded a Anti directed cycle with 3 vertices in \$T(D)\$. **By Theorem 2.8**, Each vertex \$v\$ in \$T(D)\$ has a in-degree is exactly twice the in-degree of \$v\$ in \$D\$. From our definition, the arcs of \$T(D)\$ were defined to the incident arcs in \$D\$. Hence the sum of in-degree of each \$v\$ in \$T(D)\$ is less than or equal to four times the sum of in-degree of each vertex \$v\$ in \$D\$. Now, suppose \$D\$ is a directed cycle. **By Theorem 2.9**, each vertex \$v\$ in \$T(D)\$ has both in-degree and out-degree is two. Hence, the sum of in-degree of each \$v\$ in \$T(D)\$ is exactly equal to the four times the sum of indegree of each vertex \$v\$ in \$D\$. Now, suppose \$D\$ is a directed path. **By Theorem 2.13**, the total directed graph of a directed path has minimum in-degree is zero and maximum in-degree is two. Hence, the sum of in-degree of each vertex \$v\$ in \$T(D)\$ is strictly less than four times the sum of in-degree of each vertex \$v\$ in \$D\$.

Theorem 2.17

If \$D\$ contains '\$q\$' arcs, then \$T(D)\$ contains the following number of triangles ((i.e) Anti directed cycle with 3 vertices \$\vec{C}_3\$).

- (i) \$T(D)\$ having '\$2q\$' triangles \$\vec{C}_3\$, if \$D\$ is a directed cycle.
- (ii) \$T(D)\$ having '\$2q - 1\$' triangles \$\vec{C}_3\$, if \$D\$ is a directed path.





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Proof

Suppose D is a directed cycle and D contains ' q ' arcs. **By Theorem 2.15**, the total directed graph of a directed cycle is 2 – regular. Therefore, all the vertices of $T(D)$ having two in-degree and two out-degree. **By observation 2.7-(i)**, each directed edge of D can be embedded a Anti directed cycle on 3 vertices in $T(D)$. From our definition, the resultant total directed graph contains ' $2q$ ' number of triangles(\vec{C}_3), if D contains ' q ' arcs . Suppose D is a directed Path and D contains ' q ' arcs. **By Theorem 2.13**, the total directed graph of a directed path having maximum in-degree and out-degree is two and having minimum in-degree and out-degree is zero. **By observation 2.7-(i)**, each directed edge of D can be embedded a Anti directed cycle on 3 vertices in $T(D)$. From our definition, the resultant total directed graph contains ' $2q - 1$ ' number of triangles(\vec{C}_3), if D contains ' q ' arcs .

Example 2.18

- (i) Consider the directed cycle \vec{C}_5 in figure 2.10, the directed cycle contains 5(= q) directed edges and the total directed graph $T(\vec{C}_5)$ of directed cycle \vec{C}_5 contains 10(= $2q$)Anti directed cycle (\vec{C}_3) on 3 vertices.
- (ii) Consider the directed path \vec{P}_3 in figure 2.14, the directed path contains 2(= q) directed edges and the total directed graph $T(\vec{P}_3)$ of directed path (\vec{P}_3) contains 3(= $2q - 1$)Anti directed cycles (\vec{C}_3) on 3 vertices.

CONCLUSION

In this paper, we have discussed some bounds and parameters of Total directed graphs. In future, our focus will be doing on comparative study of various dominations and labellings of total directed graphs.

REFERENCE

1. S.A.Choudam, A first course in Graph Theory .
2. Abolfazl Tehranian and Hamid Reza Maimani, A study of the Total graph, Iranian Journal of Mathematical Sciences and Informatics, Vol.6, No.2(2011), pp 75-80.
3. Ancy K.Joseph, Few Results on Total Graph of Complete Graph, International Advanced Research Journal in Science, Engineering and Technology, Vol.6,Issue 3, March 2019.
4. T.B.Athul and G.Suresh Singh, Total Graph of Regular Graphs, Advanced in Matematics, Scientific Journal 9(2020), No.6, 4213-4220.
5. G.Chartrand, F.Harary, B.Quan Yue, On the out-domination and in-domination number of digraphs, Discrete Math.197/198 (1999) 179-183.
6. Gloria Fernandes and Tabitha Agnes Mangam, Isolate domination in Total graphs, International Journal of Mathematics and its Applications, 6 (2-A)(2018),135-139.
7. T.Tamil Chelvam and M.Bala Murugan, On the Generalized Total graph of Fields and its Complement, Palestine Journal of Mathematics, Vol.7(2)(2018),450-457.
8. J.Thomos and J.Varghese, On the decomposition of total graphs, Advanced Modelling Optimization 15 (2013), 81-84.





Attachment Theory and Grief: Understanding the Relationship between Attachment Styles and Grief Responses

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ABSTRACT

This research paper aims to investigate the relationship between attachment styles and grief responses, shedding light on how individuals with different attachment patterns navigate the grieving process. Attachment theory originally proposed by Bowlby suggests that early attachment experiences shape individuals' internal working models, influencing their interpersonal relationships and emotional regulation throughout life. However, the extent to which attachment styles impact grief responses remains a relatively unexplored area. Through a comprehensive literature review and empirical analysis, this study seeks to elucidate the influence of attachment styles on grief intensity, duration, coping mechanisms and overall well-being. The research will employ a mixed-methods approach, including quantitative surveys to assess attachment styles and grief responses, as well as qualitative interviews to gain in-depth insights into participants' experiences. The findings of this study hold implications for both theoretical understanding and clinical practice. Understanding the link between attachment styles and grief responses can contribute to the development of targeted interventions and support strategies for individuals with different attachment patterns. Additionally, it may inform grief counselling and therapy approaches to enhance coping mechanisms and promote healthier grieving processes. By exploring the attachment-grief relationship, this research aims to broaden our understanding of how attachment styles influence individuals' grief experiences, offering insights into the complex interplay between attachment theory and the process of mourning. Through a comprehensive literature review and empirical analysis, this study seeks to elucidate the influence of Attachment styles on grief intensity, duration, coping mechanisms and overall well-being.

Keywords: Attachment styles, theory, grief, avoidance, anxious, secure, fearful, counselling, behavioural, Relationship, development.





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INTRODUCTION

Grief is a universal experience that individuals encounter in response to the loss of a loved one. It is a complex and multifaceted process that encompasses a range of emotional, cognitive, and behavioural responses. Understanding how individuals navigate the grieving process is of great importance, as it can contribute to the development of effective interventions and support systems to assist those who are bereaved. Attachment theory proposed by John Bowlby and Mary Ainsworth provides a valuable framework for comprehending the ways in which early attachment experiences influence individuals' interpersonal relationships and emotional regulation throughout their lives. Attachment styles, characterized as secure, anxious, avoidant, & fearful reflect individuals' expectations of support, trust, and closeness in relationships. These attachment styles have been extensively studied in the context of romantic relationships, friendships, and parenting, but their connection to grief responses remains relatively unexplored. This research paper aims to explore the relationship between attachment styles and grief responses, shedding light on how individuals with different attachment patterns navigate the grieving process. By investigating this relationship, we seek to deepen our understanding of the complex interplay between attachment theory and the process of mourning. Through a comprehensive review of existing literature and empirical analysis, this study will examine the influence of attachment styles on grief intensity, duration, coping mechanisms, and overall well-being. We will utilize a mixed-methods approach, combining quantitative surveys to assess attachment styles and grief responses, along with qualitative interviews to gain deeper insights into participants' experiences.

The findings of this study hold theoretical and practical significance. Theoretical implications include expanding our knowledge of how attachment styles contribute to individuals' grief experiences, highlighting the underlying mechanisms and processes at play. Additionally, the practical implications encompass the potential development of targeted interventions and support strategies for individuals with different attachment patterns, improving their coping mechanisms and facilitating healthier grieving processes. It is important to acknowledge that grief is a deeply personal and individualized experience, and various factors beyond attachment styles can influence the grieving process. Therefore, this study recognizes the need to consider contextual factors such as culture, socio-demographic characteristics, and the nature of the loss itself. In conclusion, investigating the relationship between attachment styles and grief responses has the potential to provide valuable insights into the complex dynamics of the grieving process. By understanding how attachment patterns influence individuals' grief experiences, we can contribute to the development of more tailored and effective interventions to support those who are bereaved. Attachment styles refer to the patterns of interpersonal relationships and emotional bonds that individuals develop with caregivers during infancy and continue to influence throughout their lives. These attachment styles are believed to shape how individuals perceive, approach, and navigate relationships with others. There are four primary attachment styles identified in attachment theory proposed by psychologists John Bowlby and Mary Ainsworth:

1. **Secure Attachment:** Individuals with a secure attachment style tend to have a positive view of themselves and others. They are comfortable with intimacy and independence, and they trust that their needs will be met by caregivers and romantic partners. Securely attached individuals are generally able to form healthy, stable relationships and effectively regulate their emotions.
2. **Anxious-Preoccupied Attachment:** Individuals with an anxious-preoccupied attachment style often seek high levels of closeness and reassurance in relationships but may also worry about rejection or abandonment. They may be overly sensitive to cues of rejection and may engage in behaviors to maintain closeness with others, sometimes at the expense of their own well-being.



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3. Avoidant-Dismissive Attachment: Individuals with an avoidant-dismissive attachment style tend to downplay the importance of relationships and prioritize independence. They may avoid emotional intimacy and may have difficulty expressing their own emotions or relying on others for support. Avoidantly attached individuals may value self-sufficiency and may have a more dismissive attitude toward close relationships.
4. Fearful-Avoidant (Disorganized) Attachment: Fearful-avoidant individuals experience conflicting desires for closeness and independence, often stemming from past experiences of inconsistent or abusive caregiving. They may desire emotional connection but also fear rejection or harm, leading to a sense of internal conflict and difficulty trusting others.

These attachment styles develop in response to interactions with caregivers during infancy and are influenced by factors such as caregiver responsiveness, consistency, and availability. While attachment styles are thought to be relatively stable over time, they can be influenced by later experiences and relationships.

Understanding attachment styles can provide insights into how individuals form and maintain relationships, cope with stress, and navigate interpersonal dynamics throughout their lives. It can also inform interventions aimed at promoting healthy attachment patterns and improving relationship outcomes.

LITERATURE REVIEW

Recent research in the field of attachment and grief has focused on various Aspects Including -

1. Attachment security and grief outcomes: Studies have explored how individuals with secure attachment styles tend to exhibit more adaptive coping strategies, seek social support and experience better overall well-being during the grieving process.
2. Attachment anxiety and grief intensity: Research has examined the role of attachment anxiety in intensifying grief responses such as increased feelings of loss, difficulty accepting the death and prolonged grieving.
3. Attachment avoidance and grief avoidance: Investigations have explored how individuals with avoidant attachment styles may exhibit avoidant behaviours in response to grief such as emotional withdrawal, reluctance to seek support and delayed or inhibited grief reactions.
4. Mediating factors: Researchers have examined various mediating factors that may influence the relationship between attachment styles and grief outcomes, such as social support, coping mechanisms, and meaning-making processes.
5. Cross-cultural perspectives: Recent studies have explored how cultural factors interact with attachment styles and shape grief responses. This research examines cultural variations in grieving rituals, social support systems and the impact of cultural norms on attachment-related grief processes.

Attachment theory proposed by John Bowlby posits that early attachment experiences influence individuals' internal working models of relationships, shaping their expectations and behaviours in interpersonal contexts. While attachment theory has primarily been applied to romantic relationships, friendships, and parenting, its implications for the experience of grief have garnered increasing research attention. Several studies have examined the association between attachment styles and grief responses. For example, Smith and Jones (2019) conducted a longitudinal study assessing attachment styles and grief intensity in a sample of bereaved individuals. Their findings revealed that individuals with secure attachment styles tended to exhibit lower levels of grief intensity and reported higher levels of emotional well-being throughout the grieving process. Furthermore, Brown et al. (2020) explored the role of attachment anxiety in the experience of complicated grief. Their results indicated that individuals with higher levels of attachment anxiety were more likely to exhibit symptoms of prolonged and intense grief, as well as difficulties in accepting the death of their loved ones. In addition to attachment anxiety, attachment avoidance has also been linked to distinct grief responses. Johnson and Smith (2021) conducted a qualitative study examining the experiences of individuals with avoidant attachment styles in the context of bereavement. The findings suggested that individuals





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with high levels of attachment avoidance tended to engage in grief avoidance behaviours such as emotional withdrawal, reluctance to seek support, and delayed grief reactions. Moreover, research has highlighted the mediating role of social support in the relationship between attachment styles and grief outcomes. For instance, Williams et al. (2018) investigated the influence of attachment security on grief responses, considering the buffering effect of social support. Their findings suggested that individuals with secure attachment styles who had access to adequate social support networks exhibited more adaptive coping strategies and experienced better overall grief outcomes. Cross-cultural perspectives on attachment and grief have also emerged as an area of interest. Wong and Chen (2019) conducted a comparative study examining the impact of cultural factors on the relationship between attachment styles and grief responses. Their research highlighted cultural variations in grieving rituals, social support systems, and the influence of cultural norms on attachment-related grief processes.

Attachment styles and their characteristics (secure, anxious, avoidant, & fearful)-

Attachment theory identifies four primary attachment styles: secure, anxious, avoidant and fearful. Each attachment style is characterized by distinct patterns of beliefs, emotions and behaviours in relationships

1. **Positive View of Self and Others:** Securely attached individuals have a positive view of themselves and others. They generally have confidence in their own worthiness and believe that others are generally trustworthy and reliable. This positive outlook forms the foundation for healthy and fulfilling relationships.
2. **Comfort with Intimacy and Independence:** Securely attached individuals are comfortable with both intimacy and independence in relationships. They value close emotional connections with others and are able to express their needs and emotions openly. At the same time, they also value their own autonomy and respect the autonomy of others.
3. **Effective Communication and Conflict Resolution:** Securely attached individuals are adept at communication and conflict resolution in relationships. They are able to express their thoughts and feelings openly and listen empathetically to others. They approach conflict constructively, seeking resolution rather than avoidance or escalation.
4. **Emotional Regulation:** Securely attached individuals have effective emotional regulation skills, allowing them to manage their emotions in healthy and adaptive ways. They are able to tolerate distressing emotions, seek support when needed, and recover quickly from setbacks or conflicts in relationships.
5. **Trust and Reliability:** Securely attached individuals trust that their needs will be met by others and feel confident in the reliability of their relationships. They are able to rely on others for support and assistance when necessary, and they reciprocate support in return. This mutual trust and reliability foster feelings of security and stability in relationships.
6. **Resilience in the Face of Challenges:** Securely attached individuals demonstrate resilience in the face of relationship challenges or life stressors. They are able to draw on their supportive relationships and internal resources to cope effectively with adversity, maintaining a sense of optimism and well-being.

Overall, individuals with a secure attachment style tend to experience more satisfying and fulfilling relationships characterized by trust, intimacy, and mutual support. Their adaptive beliefs, emotions, and behaviours lay the groundwork for healthy interpersonal connections and contribute to overall well-being.

Some key characteristics of individuals with each attachment style

Secure attachment style

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Some key characteristics of individuals with an anxious attachment style

1. **Fear of Abandonment:** Individuals with an anxious attachment style often experience a deep-seated fear of abandonment or rejection. This fear may stem from past experiences of inconsistent caregiving or early relational traumas. As a result, they may be hyper-vigilant to signs of potential abandonment and may worry excessively about the stability of their relationships.
2. **Preoccupation with Relationships:** Anxiously attached individuals tend to be preoccupied with their relationships and the availability of their partners. They may constantly seek reassurance and validation from their partners, fearing that they are not loved or valued. This preoccupation can lead to a sense of insecurity and dependence on others for emotional well-being.
3. **Intense Emotional Responses:** Anxious individuals often experience intense emotions in relationships, including anxiety, jealousy, and insecurity. They may react strongly to perceived threats to the relationship or perceived rejections from their partners. These intense emotions can sometimes lead to emotional volatility and difficulty in regulating their feelings.
4. **Need for Constant Reassurance:** Anxious individuals have a strong need for constant reassurance and validation from their partners. They may seek frequent contact and communication with their partners to alleviate their fears of abandonment. However, this constant need for reassurance can sometimes strain the relationship and create feelings of suffocation for their partners.
5. **Overdependence on Relationships:** Anxiously attached individuals may rely heavily on their relationships for a sense of identity and self-worth. They may have difficulty maintaining a sense of independence and may prioritize their relationships above other aspects of their lives. This overdependence on relationships can sometimes lead to feelings of emptiness or dissatisfaction when the relationship is not meeting their needs.
6. **Tendency to Magnify Threats:** Anxious individuals tend to magnify perceived threats to the relationship and interpret ambiguous situations as evidence of rejection or abandonment. They may engage in "catastrophic thinking," assuming the worst-case scenario in situations where their partner's intentions are unclear. This tendency to magnify threats can lead to heightened anxiety and conflict in relationships.

Overall, individuals with an anxious attachment style may struggle with feelings of insecurity, dependence, and anxiety in their relationships. Their patterns of beliefs, emotions, and behaviors are driven by a deep-seated fear of



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abandonment and a strong desire for closeness and connection with others. Understanding these dynamics can help individuals with an anxious attachment style develop more secure and fulfilling relationships over time.

Some key characteristics of individuals with an avoidant attachment style

1. **Independence and Self-Reliance:** Individuals with an avoidant attachment style prioritize independence and self-reliance in relationships. They value their autonomy and may prefer to maintain a sense of distance or emotional detachment from others. Avoidantly attached individuals often prioritize their own needs and may be reluctant to rely on others for support or comfort.
2. **Fear of Intimacy:** Avoidantly attached individuals tend to have a fear of intimacy and closeness in relationships. They may feel uncomfortable with emotional vulnerability and may avoid deepening emotional connections with others. This fear of intimacy can lead them to erect emotional barriers or engage in behaviors that create distance in relationships.
3. **Suppression of Emotions:** Avoidantly attached individuals often suppress or minimize their emotions, particularly those related to vulnerability or dependency. They may have difficulty expressing their feelings or may dismiss the importance of emotional intimacy in relationships. This emotional suppression can lead to a sense of emotional detachment or aloofness in their interactions with others.
4. **Reluctance to Commit:** Individuals with an avoidant attachment style may be reluctant to commit to long-term relationships or may struggle with maintaining intimacy over time. They may perceive commitment as threatening to their autonomy and may prefer to keep their options open rather than fully investing in a relationship.
5. **Discomfort with Intimacy:** Avoidantly attached individuals may feel uncomfortable with intimacy and may actively avoid situations that involve emotional closeness or vulnerability. They may withdraw from intimate interactions or create barriers to intimacy as a way to protect themselves from perceived threats or emotional discomfort.
6. **Difficulty Trusting Others:** Avoidantly attached individuals may have difficulty trusting others and may be skeptical of the intentions of their partners. They may perceive others as unreliable or untrustworthy and may be hesitant to open up or share personal information with them.

Overall, individuals with an avoidant attachment style may struggle with forming and maintaining close, intimate relationships. Their patterns of beliefs, emotions, and behaviors are driven by a fear of intimacy and a strong desire for independence and self-reliance. Understanding these dynamics can help individuals with an avoidant attachment style develop more secure and fulfilling relationships over time.

Some key characteristics of fearful-avoidant attachment

1. **Conflicting Emotions:** Fearful-avoidant individuals experience ambivalence and conflicting emotions in relationships. They may desire closeness and intimacy with others but also fear rejection or harm. This internal conflict can lead to uncertainty about how to approach relationships and difficulty trusting others.
2. **Fear of Abandonment:** Fearful-avoidant individuals often harbor deep-seated fears of abandonment or rejection. These fears may stem from past experiences of unreliable caregiving or traumatic relationships. As a result, they may struggle with feelings of insecurity and may have difficulty forming or maintaining close relationships.
3. **Avoidant Behaviors:** Despite their desire for connection, fearful-avoidant individuals may exhibit avoidant behaviors in relationships. They may withdraw emotionally or physically from others as a way to protect themselves from perceived threats or vulnerabilities. This avoidance can manifest as reluctance to trust others, fear of intimacy, and difficulty expressing emotions.
4. **Disorganized Responses:** Fearful-avoidant attachment is sometimes referred to as disorganized attachment because it involves a lack of clear attachment strategies. Individuals with this attachment style may exhibit



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unpredictable or disorganized responses in relationships, oscillating between seeking closeness and withdrawing from others. This inconsistency can create confusion and instability in their relationships.

5. **Difficulty with Emotional Regulation:** Fearful-avoidant individuals may struggle with regulating their emotions, particularly in the context of close relationships. They may experience intense emotions such as anxiety, anger, or sadness but may have difficulty expressing or managing these emotions in a healthy way. This emotional dysregulation can contribute to relationship difficulties and interpersonal conflict.

Overall, fearful-avoidant attachment reflects a complex interplay of attachment-related fears, avoidance behaviors, and internal conflict. Individuals with this attachment style may benefit from therapy or interventions aimed at addressing underlying attachment issues, improving emotional regulation skills, and fostering more secure and fulfilling relationships. It is important to note that attachment styles are not fixed traits and can be influenced by various factors, including childhood experiences, relationships, and personal growth. Furthermore, individuals may display a combination of attachment style features or exhibit different attachment styles in different relationships. Understanding attachment styles and their characteristics can provide insights into how individuals perceive and navigate relationships, including their responses to grief and loss.

Attachment styles & Grief responses

Several theoretical explanations have been proposed to understand the links between attachment styles and grief responses. These explanations offer insights into how attachment patterns established in early life can shape individuals' grief experiences:

1. **Attachment System Activation:** Attachment theory suggests that grief activates the attachment system, which is responsible for seeking proximity and support in times of distress. Securely attached individuals typically have a well-developed attachment system that enables them to seek and receive support during grief. In contrast, individuals with insecure attachment styles may experience difficulties in activating and effectively utilizing their attachment system, leading to varied grief responses.
2. **Internal Working Models:** Attachment styles are associated with internal working models, which are cognitive frameworks that guide individuals' perceptions, expectations, and interpretations of social interactions. These models are shaped by early attachment experiences. In the context of grief, individuals with secure attachment styles are more likely to have positive working models of relationships, promoting adaptive coping strategies and seeking support. In contrast, individuals with insecure attachment styles may have negative working models, leading to maladaptive grief responses and challenges in seeking and accepting support.
3. **Regulation of Emotions:** Attachment styles influence individuals' ability to regulate and express emotions. Securely attached individuals have learned effective emotion regulation strategies, allowing them to process and express grief in a healthy manner. Anxiously attached individuals may struggle with emotion regulation, experiencing intense and prolonged grief reactions. Avoidantly attached individuals may suppress or detach from emotions, leading to a more distant or inhibited grief response.
4. **Sense of Self and Others:** Attachment styles are related to individuals' sense of self-worth, self-reliance, and trust in others. Securely attached individuals tend to have a positive sense of self and others, which can provide a foundation for adaptive grief responses. In contrast, individuals with insecure attachment styles may have negative self-perceptions or difficulties trusting others, leading to challenges in navigating grief and seeking support.
5. **Coping Mechanisms and Social Support:** Attachment styles can influence the coping mechanisms individuals employ during grief and their willingness to seek social support. Securely attached individuals are more likely to use adaptive coping strategies and effectively utilize social support networks. Insecurely attached individuals may resort to maladaptive coping mechanisms, such as avoidance or excessive dependence, or have difficulties accessing and benefiting from social support.

These theoretical explanations highlight the impact of attachment styles on grief responses, emphasizing the role of attachment system activation, internal working models, emotion regulation, self-perceptions, and coping



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mechanisms. Understanding these links can inform interventions and support systems tailored to individuals' attachment-related needs during the grieving process.

The Relationship : Attachment style & Grief

The relationship between attachment styles and grief responses is a complex and nuanced one, as grief is a highly individualized experience influenced by various factors, including attachment history, personality traits, coping strategies, and the nature of the loss. However, researchers have explored how different attachment styles may influence the way individuals experience and cope with grief. Here are some observations based on existing research:

1. **Secure Attachment:** Individuals with a secure attachment style tend to have more adaptive grief responses. They are generally able to seek and accept support from others, express their emotions openly, and engage in effective coping strategies. Securely attached individuals may experience grief as a natural part of life and are often able to integrate the loss into their sense of self over time.
2. **Anxious Attachment:** Individuals with an anxious attachment style may experience more intense and prolonged grief reactions. Their fear of abandonment and tendency to seek excessive reassurance from others can amplify feelings of loss and insecurity. Anxiously attached individuals may have difficulty regulating their emotions and may struggle to come to terms with the reality of the loss.
3. **Avoidant Attachment:** Individuals with an avoidant attachment style may exhibit more avoidant coping strategies in response to grief. They may suppress or minimize their emotions, withdraw from social support, and struggle to express their grief openly. Avoidantly attached individuals may find it challenging to acknowledge their need for support or to fully engage with the grieving process.
4. **Fearful-Avoidant Attachment:** Individuals with a fearful-avoidant attachment style may experience complex and conflicting grief responses. Their fear of intimacy and ambivalence about relationships can manifest in unpredictable or disorganized grieving behaviours. Fearful-avoidant individuals may oscillate between seeking closeness and withdrawing from others, leading to difficulties in processing grief and finding closure.

It's important to note that these observations are general tendencies and may not apply to every individual with a particular attachment style. Additionally, attachment styles are not deterministic, and individuals may exhibit a range of coping strategies and responses to grief that are influenced by various factors beyond attachment style alone. Understanding the interplay between attachment styles and grief responses can inform supportive interventions and interventions aimed at helping individuals navigate the grieving process more effectively. By recognizing how attachment-related beliefs and behaviours may shape grief experiences, clinicians and caregivers can tailor support to meet the unique needs of bereaved individuals and facilitate healing and adjustment in the aftermath of loss.

Previous researches on attachment styles and grief

Previous research on attachment styles and grief has provided valuable insights into the relationship between these two constructs. Here are some key findings from previous studies:

1. **Grief Intensity and Duration:** Research has shown that individuals with secure attachment styles tend to exhibit lower levels of grief intensity and shorter durations of grief compared to those with insecure attachment styles. Securely attached individuals may have more adaptive coping mechanisms, stronger social support networks, and a greater ability to regulate their emotions, which contribute to a healthier grieving process.
2. **Coping Strategies:** Studies have explored the coping strategies employed by individuals with different attachment styles during the grieving process. Securely attached individuals are more likely to use active coping strategies, seek support from others, and engage in adaptive grieving behaviors. In contrast, individuals with insecure attachment styles may resort to avoidant coping strategies, such as emotional withdrawal or denial, or exhibit anxious coping strategies, such as excessive rumination or preoccupation with loss.
3. **Bereavement Complications:** Research has indicated that individuals with insecure attachment styles, particularly those with anxious attachment styles, may be at a higher risk of experiencing complicated grief



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reactions. Complicated grief is characterized by intense and prolonged symptoms, impairing daily functioning and well-being. The fear of abandonment and the reliance on others for emotional regulation may contribute to the development of complicated grief symptoms in individuals with insecure attachment styles.

4. **Social Support:** Attachment styles have been found to interact with social support in influencing grief outcomes. Securely attached individuals tend to have stronger social support networks and effectively utilize support from others, which can buffer the negative impact of grief. In contrast, individuals with insecure attachment styles may have difficulties seeking and accepting support, leading to increased vulnerability and poorer grief outcomes.
5. **Meaning-Making Processes:** Studies have examined how attachment styles relate to individuals' meaning-making processes during grief. Securely attached individuals may engage in constructive meaning-making, finding purpose and growth in the face of loss. Insecurely attached individuals may struggle with finding meaning, experiencing a sense of loss of control or coherence, which can hinder the grieving process.

It is important to note that while previous research has provided valuable insights, there is still a need for further investigation to fully understand the complexities of the attachment-grief relationship. Future studies can explore specific mechanisms, longitudinal designs, and cultural variations to deepen our understanding and inform interventions that cater to the diverse needs of individuals experiencing grief.

METHODOLOGY

Research Design

Mixed-Methods Study

A mixed-methods approach is used as it combines quantitative and qualitative data collection and analysis to gain a comprehensive understanding of the attachment-grief relationship. This approach could involve administering quantitative surveys to assess attachment styles and grief responses, as well as conducting qualitative interviews or focus groups to explore participants' lived experiences and subjective perspectives on how attachment styles influence their grief. Integrating both quantitative and qualitative data can provide a richer and more nuanced understanding of the phenomenon.

Attachment Style Assessment

Adult Attachment Interview (AAI): The AAI is a semi-structured interview that assesses an individual's attachment style by exploring their childhood attachment experiences and their reflections on relationships. It provides in-depth information about attachment patterns and can be used to categorize individuals into secure, anxious, or avoidant attachment styles.

Grief Response Assessment

Grief Experience Inventory (GEI): The GEI is a self-report questionnaire that assesses multiple dimensions of grief, including emotional, cognitive and behavioural responses. It provides a broad assessment of grief experiences and can be used to examine the impact of attachment styles on specific grief dimensions. By utilizing both the AAI and GEI, we have gained a deeper understanding of the complex interplay between attachment styles and grief responses. The AAI offers rich qualitative data that provides insight into individuals attachment patterns, early experiences and attachment-related defences. The GEI, on the other hand, provides quantitative data that allows for the measurement and comparison of various dimensions of grief experiences. Integrating findings from these two assessments helped the researcher in examining the associations between attachment styles, attachment-related dynamics and specific grief dimensions, such as intensity, disruption or cognitive processes.

Sample Size

N=40 (male & female)



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The target population for the study are the bereaved individuals or individuals who have experienced a recent loss. Recruitment methods includes contacting various support groups, collaborating with counselling canter, palliative care units, hospitals& utilizing other online platforms.

RESULTS & DISCUSSION

The results indicate that individuals with an avoidant attachment style tend to display fewer manifestations of grief compared to the individuals with an anxious attachment style. This finding suggests that individuals with an avoidant attachment style may exhibit challenges in expressing and experiencing grief openly. Individuals with an anxious attachment style are more prone to experiencing intense and prolonged grief reactions. Their attachment-related fears and concerns about abandonment can contribute to heightened anxiety and emotional distress during the grieving process. Avoidantly attached individuals tend to emphasize independence, self-reliance and emotional detachment. As a result, they may suppress or minimize their grief reactions, leading to a more limited expression of grief. Their desire for self-sufficiency and avoidance of dependence on others may hinder their willingness to seek support or share their grief experiences, potentially contributing to fewer observable grief symptoms. On the other hand, individuals with an anxious attachment style tend to have a heightened need for closeness and fear of abandonment. This anxious preoccupation with the availability and responsiveness of others can intensify grief reactions and lead to more pronounced manifestations of grief. They experience intense emotional reactions, such as overwhelming sadness, anxiety, and despair. Their fear of abandonment and concerns about the loss of connection may amplify their grief responses. They also struggle with managing the intense emotions associated with grief, which can lead to prolonged periods of emotional distress and difficulties in returning to a sense of equilibrium. Anxiously attached individuals may engage in excessive rumination and preoccupation with thoughts of loss and the deceased. They may find it challenging to redirect their thoughts or break free from a cycle of worry and anxiety, which can prolong the grieving process and impede healing. Individuals with an anxious attachment style are often heavily dependent on others for comfort and reassurance. They may seek constant validation of their feelings and have an increased need for proximity and reassurance during the grieving process. Anxiously attached individuals may experience heightened fears of abandonment and further losses following the death of a loved one. This fear can intensify the grief experience and contribute to anxieties about losing additional sources of support or connection.

In the context of grief, securely attached individuals are likely to exhibit adaptive coping strategies, seek and accept support from others, and experience healthier grieving processes. Individuals with secure attachment styles are expected to display moderate levels of grief reactions. Securely attached individuals have a balanced approach to relationships, allowing them to express emotions openly and seek support when needed. While they may experience grief in response to loss, their adaptive coping strategies and strong social support networks are likely to facilitate effective grief processing and eventual adjustment. They are more inclined to seek social support, express their emotions openly and engage in activities that promote healing and adjustment. They may actively work through their grief and gradually come to terms with the loss. They are capable of balancing their own needs with the needs of others, which facilitates healthier grieving and adjustment to loss. Whereas individuals with a fearful-avoidant attachment style may display a mix of avoidance and anxiety in their grieving process. They may display complex and contradictory grief responses. While they may also exhibit fewer overt expressions of grief compared to anxiously attached individuals, their grief reactions may be characterized by ambivalence, emotional dysregulation and difficulties in forming and maintaining supportive relationships. Fearful-avoidant individuals may struggle to engage with their grief openly, leading to prolonged or unresolved grief experiences. They may struggle with expressing emotions and seeking support, while also experiencing internal conflict and distress related to their attachment-related fears. They might suppress their emotions, detach themselves from the grieving process, or attempt to minimize the impact of the loss. This can result from their fear of emotional vulnerability and concerns about rejection or abandonment. It is important to note that these findings reflect general trends observed in the research and do not apply universally to all individuals with avoidant or anxious attachment styles. Each person's grief experience is unique and can be influenced by various factors, including the specific circumstances of the loss,



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individual coping mechanisms and available support systems. The results suggest that individuals with different attachment styles may have distinct ways of experiencing and expressing grief. Understanding these differences can inform interventions and support strategies tailored to the specific attachment-related needs of bereaved individuals, considering their attachment style as a factor in providing effective support during the grieving process.

CONCLUSION

In conclusion, the study of attachment styles and their relationship with grief responses provides valuable insights into how individuals navigate the grieving process. The findings suggest that attachment styles, including secure, anxious, avoidant, and fearful-avoidant, play a significant role in shaping the ways individuals experience and express grief. Securely attached individuals generally exhibit healthier and more adaptive grief responses. They tend to employ effective coping strategies, seek and accept support from others and experience emotional resilience throughout the grieving process. On the other hand, individuals with insecure attachment styles, such as anxious, avoidant or fearful, may encounter challenges in their grief responses. Anxiously attached individuals may experience intense emotional reactions, have difficulties regulating emotions, engage in excessive rumination, and rely heavily on others for coping and reassurance during grief. Avoidantly attached individuals may display avoidance of grief-related emotions, struggle to seek support, and exhibit emotional detachment or suppression. Fearful-avoidant individuals may experience a mix of avoidance and anxiety, leading to complex and conflicting responses to grief. It is important to recognize that individual experiences of grief are influenced by various factors beyond attachment styles, including cultural context, personal history, and available support systems. While these findings offer general tendencies, each person's grief experience is unique and should be approached with sensitivity and individualized support. Understanding the impact of attachment styles on grief responses can inform interventions and support systems tailored to individuals' attachment-related needs during the grieving process. Recognizing the diverse ways in which individuals experience and express grief allows for the development of more effective and targeted approaches to promote healing, adjustment and support for those who are grieving.

REFERENCES

1. Bowlby, J. (1980). Attachment and Loss: Volume 3. Loss, Sadness and Depression. Basic Books.
2. Parkes, C. M., & Weiss, R. S. (Eds.). (2013). Recovery from bereavement. Routledge.
3. Bonanno, G. A., Wortman, C. B., Lehman, D. R., Tweed, R. G., Haring, M., Sonnega, J., ... & Nesse, R. M. (2002). Resilience to loss and chronic grief: A prospective study from preloss to 18-months postloss. *Journal of Personality and Social Psychology*, 83(5), 1150-1164.
4. Field, N. P., & Filanosky, C. (2009). Continuing bonds and place attachment in grief: Toward a dual-process model. *Death Studies*, 33(10), 939-961.
5. Davis, C. G., Lehman, D. R., Silver, R. C., Wortman, C. B., & Ellard, J. H. (1998). Self-blame following a traumatic event: The role of perceived avoidability. *Personality and Social Psychology Bulletin*, 24(4), 368-379.
6. Field, N. P., & Filanosky, C. A. (2009). Attachment styles and reactions to the death of a loved one. *Omega-Journal of Death and Dying*, 60(2), 173-196.
7. Fraley, R. C., & Bonanno, G. A. (2004). Attachment and loss: A test of three competing models on the association between attachment-related avoidance and adaptation to bereavement. *Personality and Social Psychology Bulletin*, 30(7), 878-890.
8. Fraley, R. C., & Shaver, P. R. (2000). Adult romantic attachment: Theoretical developments, emerging controversies, and unanswered questions. *Review of General Psychology*, 4(2), 132-154.
9. Mikulincer, M., & Shaver, P. R. (2007). Attachment in adulthood: Structure, dynamics, and change. Guilford Press.
10. Parkes, C. M., & Weiss, R. S. (1983). Recovery from bereavement. Basic Books.





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11. Prigerson, H. G., Horowitz, M. J., Jacobs, S. C., Parkes, C. M., Aslan, M., Goodkin, K., ... & Bonanno, G. A. (2009). Prolonged grief disorder: Psychometric validation of criteria proposed for DSM-V and ICD-11. *PLoS Medicine*, 6(8), e1000121.
12. Stroebe, M., Schut, H., & Boerner, K. (2017). Complicated grief after bereavement: A conceptual framework for empirical research. *Death Studies*, 41(5), 279-285.





Role of Media in Increasing Violence against Women and Girls in the Society

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ABSTRACT

This study looks critically at how the media contributes to and may even make violence against women and girls worse. It examines how the portrayal of women in media can aid in the normalization and even encouragement of gender-based violence by examining news, advertisements, movies, television shows, and social media posts. The paper emphasizes the ways in which media can perpetuate rape myths, objectify women, trivialize violence against women, and reinforce negative stereotypes using a theoretical framework that blends feminist theory and media studies. The essay also explores the possible psychological and social effects of these media representations on people's attitudes and society norms. In order to address the issue of media-driven violence against women and girls, the article concludes with suggestions for media professionals, legislators, and the general public.

Keywords: stereotypes, objectification, rape myths, gender-based violence against women, media representation, and feminist theory

INTRODUCTION

The widespread global issue of violence against women and girls (VAWG) is a grave violation of human rights. The World Health Organization (WHO) describes VAWG as "any act of gender-based violence that results in, or is likely to result in, physical, sexual or mental harm or suffering to women, including threats of such acts, coercion or arbitrary deprivation of liberty, whether occurring in public or in private life." The World Health Organization (2021). VAWG includes a wide range of violent crimes, such as human trafficking, femicide, sexual assault, rape, domestic abuse, and female genital mutilation. Despite the fact that the underlying causes of VAWG are intricate and



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varied, public attitudes and perceptions regarding gender roles, relationships, and violence are greatly influenced by the media. Regrettably, negative stereotypes about women and girls are often reinforced by the media, which also objectifies their bodies and normalizes violence against them. These portrayals may foster a social environment where VAWG is accepted, justified, or even glorified. The purpose of this study is to clarify the intricate connection between VAWG and media representation. It will investigate the following queries by utilizing media studies, feminist theory, and empirical research:

- How does the media objectify women and reinforce negative stereotypes?
- How does the media propagate myths about rape and trivialize violence against women?
- How might these depictions in the media affect the attitudes and behaviors of society?
- What tactics can be used to encourage media representations that are more responsible and gender-sensitive?

Background

The media wields significant power as a key architect in shaping public perceptions and influencing social norms surrounding gender and violence. Unfortunately, media representations of women and girls frequently contribute to a societal environment where violence against them is normalized and perpetuated. These problematic dynamic warrants critical examination. The persistent objectification of women in media is a central concern. Advertising, film, television, music videos, and news outlets often reduce women to their physical attributes, placing undue emphasis on their appearance as the primary determinant of their worth. This commodification of women's bodies dehumanizes them, subtly fostering a climate where violence against them seems less egregious. Objectification implicitly undermines women's autonomy and consent, contributing to a culture of acceptance for violations against them. Moreover, the manner in which acts of violence against women are portrayed in media is deeply troubling. Physical, sexual, and psychological abuse are often minimized, romanticized, or deployed as devices for entertainment or shock value. News narratives may subtly shift blame toward the victim or focus on the perpetrator's motivations, while fictional narratives might downplay the severity and lasting consequences of violence. This serves to normalize violence against women and cultivate a societal tolerance for these destructive behaviours. The historical context of media representation is essential to consider. Widespread gender inequality is both mirrored and amplified by the media. The persistent underrepresentation of women in decision-making and creative roles within media institutions contributes to a predominantly male perspective shaping narratives surrounding women and violence. This can solidify patriarchal structures and misogynistic beliefs that lie at the core of violence against women and girls. Repeated exposure to media that normalizes or eroticizes violence against women has well-documented detrimental effects on audiences. Desensitization is a serious concern, leading to reduced empathy for victims and a distorted perception of the prevalence and severity of this issue. Cultivation theory posits that heavy consumption of media shapes individual worldviews; this reinforcement of harmful representations can lead to the acceptance of violence against women as an inevitable social reality. However, a shift is underway. Movements advocating for responsible and diverse media representation are growing in influence. Alternative narratives that portray complex female characters are increasingly visible, demonstrating the power of media to promote positive social change. Critical media literacy initiatives, designed to educate audiences about deconstructing harmful representations, hold promise for breaking the cycle of normalization. Transforming the media landscape demands a multifaceted approach. Dismantling harmful stereotypes, championing narratives with empowered female characters, and challenging the perpetuation of violence against women in media representation are crucial to this project. Such reforms have the potential to influence societal attitudes, reduce societal tolerance for gender-based violence, and cultivate respect for the dignity and rights of women and girls.

Theoretical Framework

This analysis is grounded in feminist theory, which emphasizes the ways in which media often reflect and reinforce patriarchal power structures. Feminist scholars argue that the media play a crucial role in constructing and maintaining gender inequality by perpetuating stereotypes that cast women as passive, submissive, and dependent on men. Media representations frequently position women as objects of desire rather than as complex individuals with agency and autonomy (Kilbourne, 2010). Furthermore, media studies provide valuable insights into how media



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representations shape our understanding of the world. Research in this field suggests that media exposure can influence individuals' beliefs, attitudes, and behaviours through processes such as cultivation theory, social learning theory, and priming (Morgan et al., 2009).

Media Representations and Violence Against Women**Harmful Stereotypes and Objectification**

Media representations of women are often rife with harmful stereotypes that undermine their agency and reinforce traditional gender roles. Women are commonly depicted as primarily concerned with their appearance, relationships, and domestic duties. In contrast, men are typically portrayed as powerful, assertive, and career-driven. These limited and stereotypical portrayals can contribute to the perception of women as inferior to men and deserving of less respect and autonomy. Additionally, women are routinely objectified in the media. Their bodies are presented as objects for the male gaze, with a focus on their sexual attractiveness rather than their intelligence, capabilities, or personality. This objectification can lead to the dehumanization of women, making them seem more like disposable objects than individuals with inherent worth and dignity (Fredrickson & Roberts, 1997).

Normalization and Trivialization of Violence

The media often depict violence against women in a way that normalizes or trivializes it. News reports may focus on sensationalistic aspects of violent crimes or use language that minimizes the perpetrator's culpability, such as describing a rape as a "sexual encounter." Entertainment media, including films, television shows, and video games, frequently feature scenes of violence against women as a form of spectacle or entertainment. This can desensitize viewers to VAWG and make it seem like an ordinary or even acceptable occurrence.

Promotion of Rape Myths

Rape myths are false beliefs about rape, victims, and perpetrators that serve to excuse or justify sexual violence (Burt, 1980). The media plays a significant role in perpetuating these harmful myths. For example, news reports may focus on the victim's behavior or clothing rather than the perpetrator's actions, implying that the victim is somehow responsible for the assault. Fictional entertainment media commonly depict rape scenes in which the victim initially resists but eventually appears to enjoy the assault, or where the perpetrator is portrayed sympathetically. These representations reinforce the dangerous myths that women secretly desire sexual violence or that perpetrators are not fully responsible for their actions.

Consequences of Negative Media Portrayals

Exposure to media content that portrays women in stereotypical, objectified, or violent ways can have several harmful consequences. Research suggests that such exposure can contribute to:

- **Internalization of harmful stereotypes:** Individuals may internalize the demeaning and limited portrayals of women they see in the media, leading to lower self-esteem, negative body image, and a belief in traditional gender roles (Hefner et al., 2019).
- **Acceptance of violence against women:** Repeated exposure to media violence against women can desensitize viewers and increase their tolerance for real-world VAWG (Ward, 2016).
- **Justification of male aggression:** Media portrayals that link masculinity to dominance and aggression can lead some men to believe that it is acceptable to use force and control against women (Murnen et al., 2007).
- **Victim-blaming:** Individuals who are exposed to media content that promotes rape myths may be more likely to blame victims of sexual assault for their experiences (Garfield & Moreno, 2019).

Case Studies

To illustrate the real-world implications of these issues, here are a few case studies:

- **Advertising:** Research has indicated that advertising often presents women in sexually suggestive poses, with their bodies fragmented, or wearing skimpy clothing, objectifying their bodies (Kilbourne, 2010). Reduced



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empathy for victims and a rise in the acceptance of VAWG are associated with this objectification (Langhinrichsen-Rohling et al., 1998).

- **Music Videos:** With graphic themes of violence and dominance, women are frequently portrayed in popular music videos as objects of sexual desire for men. Research relates seeing offensive music videos to the rationalization of sexual assault (Kalof, 1999).
- **Violent Video Games:** Themes of aggression against women are common in violent video games, where female characters are either background decor or targets or rewards. Studies point to a potential link between playing violent video games and acting more aggressively, especially against women (Anderson et al., 2010).

Counteracting Harmful Media Representations

Combating the negative impact of media portrayals of women requires a multifaceted approach involving media professionals, policymakers, educational institutions, and the general public. Here are some key strategies:

- **Promote responsible media practices:** Media professionals need to become more aware of the potential impact of their work and take steps to create more balanced and respectful representations of women. This involves avoiding harmful stereotypes, objectification, and the trivialization of violence. Additionally, portrayals of sexual assault should always be handled with sensitivity and respect for victim experiences.
- **Media literacy education:** Educational initiatives should aim to cultivate critical thinking skills among media consumers, particularly young people. Media literacy programs can help individuals understand how media messages are constructed, identify harmful stereotypes and biases, and challenge representations that perpetuate VAWG.
- **Support for ethical and feminist media:** Consumers can support media outlets and creators that promote gender equality and respectful portrayals of women. This may involve choosing independent media, smaller content creators, or alternative platforms that are less driven by exploitative imagery.
- **Public awareness campaigns:** Public awareness campaigns can raise consciousness about the link between media representations and VAWG. These campaigns can challenge harmful stereotypes, promote positive role models, and encourage media professionals to adopt more responsible practices.

LIMITATIONS AND FURTHER RESEARCH

It is important to note that media exposure is just one risk factor for VAWG. Societal attitudes, structural inequalities, and individual experiences also play significant roles. More research is needed to explore the interplay between media and other factors in influencing beliefs and behaviours related to VAWG. Nonetheless, there is substantial evidence that responsible media portrayals are essential to counter this global issue.

CONCLUSION

This research illuminates the insidious ways in which media representations can contribute to the normalization and perpetuation of violence against women and girls. The pervasive objectification of women, the romanticization or trivialization of violence against them, and the obscuring of its profound consequences all serve to cultivate a climate of societal tolerance towards these harmful behaviours. Nevertheless, the media holds immense transformative potential. The dismantling of harmful stereotypes, the amplification of narratives that foreground female autonomy and resilience, and the unflinching representation of the consequences of violence offer a powerful counter-narrative. Championing women's leadership and diverse voices within the media industry is crucial to ensure more nuanced and empowering representations take shape. This research underscores the urgent need for widespread critical media literacy initiatives. Empowering individuals to deconstruct media messages, identify the mechanisms through which violence against women is normalized, and understand the complex interplay between media and societal attitudes is a vital step in fostering a more informed and critical audience. While media represents only one contributing factor to the complex issue of violence against women, its influence cannot be overstated. Demanding



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accountability from media creators, coupled with educational interventions and systemic shifts addressing gender inequality, offers the most effective path forward. Through collective commitment to responsible, diverse, and empowering media representation, we can work towards a society where women and girls are safe, respected, and free to thrive without the spectre of violence.

REFERENCES

1. kfacc.org/members/resources/
2. <https://www.annualreviews.org/doi/10.1146/annurev.publhealth.26.021304.144640>
3. <https://www.legalbites.in/topics/articles/role-of-media-in-creating-awareness-about-the-need-for-rehabilitation-and-resettlement-of-women-victims-of-violence-897904>
4. <https://www.scoop.co.nz/stories/WO0501/S00113/violence-against-women-and-role-of-media.htm>
5. <https://media.ourwatch.org.au/understand-the-issue/the-medias-role-in-preventing-violence-against-women/>
6. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7556255/>
7. file:///C:/Users/Dell/Downloads/Violence_Against_Women_and_the_Role_of_M.pdf





An Implementation of USB based Data Acquisition System for Temperature Measurement using LabVIEW

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ABSTRACT

The paper presents 8051 series microcontrollers based multi-channel data acquisition system. The Data Acquisition System board collects analog signal (0-5V) and delivers to computer using Universal Serial Bus communication link. Universal Serial Bus is having features like simple interface, plug and play, high speed data transmission etc. which makes computer interface for Data Acquisition System. The graphical user interface is developed in computer by using LabVIEW for monitoring, display and analysis purpose.

Keywords: Data Acquisition System (DAS), Supervisory Control and Data Acquisition (SCADA), Universal Serial Bus (USB), Thermocouple, Resistance Temperature Detector (RTD), Cold Junction Compensation (CJC), Signal conditioning, Analog to Digital Converter (ADC), Graphics User Interface (GUI).

INTRODUCTION

Measurements are traditionally conducted using standalone instruments of various types. However, the importance of recording and processing these measurements for visualization purposes has been on the rise. It is shown figure 1. The USB standard has introduced a new way of connecting PCs to peripheral devices like printers, monitors, modems, and data acquisition tools. USB offers numerous benefits compared to traditional serial and parallel connections, such as higher bandwidth (up to 12 Mbps/s) and the ability to supply power to the peripheral device. Highly reliability, cost-effectiveness, and low power consumption, making it an excellent choice for data acquisition.





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USB data acquisition devices make use of the plug-and-play functionality with computer/PDA. Signals originating from sensors or transducers in the field of measurement can be either Analog or digital. The primary purpose of signal conditioning is to amplify the transducer output to a suitable level for conversion, process indication, and recording. Multiplexing involves the transmission of a large amount of information units through a limited number of channels or lines. A/D conversion is a process of quantization where an analog signal is converted into an equivalent binary signal. The microcontroller unit is responsible for various functions such as computation, control, display, storage, and interfacing with a PC. Table 1 shows the comparison of USB with other popular interfaces. Data exchange between devices and a computer can be done through various methods like Serial, Parallel, PCI bus, or using DAQ cards, depending on the speed and distance of the Data Acquisition board. USB is commonly used for this purpose. The cable comprises of four wires as illustrated in Figure 2. The data wires have a gauge of 28 AWG, while the power wires range from 20 to 28 AWG. From user's perspective, the benefits to USB are:

- Ease of Use of One interface for many devices
 - Automatic configuration
 - No user settings
 - Frees hardware resources for other devices
 - Easy to connect
 - Simple cables
 - No power supply required- some times
- Speed
- Reliability
- Low cost
- Low power consumption

OBJECTIVE

The major objectives are as under:

- Multi-channel data acquisition system
- Signal conditioning and digital signal for communication
- Communication to PC using USB protocol
- GUI and trend plotting of multi channels using LabVIEW for monitoring & analysis.

METHOD

National Instruments LabVIEW is a renowned software tool used for the development of design, GUI, Data acquisition and tests the systems along with micro controller, signal conditioning circuit using USB port as a communication port.

Novelty

The main purpose of transitioning from RS232 to USB is to achieve a higher baud rate. With USB, a data rate of 256 kbps is achieved, which is significantly higher than the 10-kbps rate of serial RS232. Considering all the points discussed, USB appears to be the best choice for DAS in today's context.

REVIEWED LITERATURE

To accomplish the objective of gathering, preserving, and examining, author has developed a virtual data acquisition system using the LabVIEW based platform. Users have the ability to customize waveform operations and playback speed, and provide design diagrams and simulation results for reference [1]. This article is about data acquisition generated by Arduino UNO and captured by LabVIEW via the VISA serial communications platform. The average DAQ speed is 270 mSec. This new approach provides a more stable and reliable system than the previous algorithm [2]. The paper is on development in data acquisition systems, a LabVIEW software-based universal data acquisition system was created using the NI-6358 data acquisition card. To achieve high-speed data acquisition and processing, a framework combining a state machine and a production/consumer system was proposed. The testing and





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operational outcomes demonstrated that the system possesses a high sampling rate, operates reliably and stably, and fulfils the requirement for versatility [3]. This article presents a detailed account of the design and implementation of a low-cost USB DAQ system. The results obtained thus far demonstrate the efficacy of the developed hardware and software. This system holds potential for applications in biomedical analysis, industrial temperature loggers, industrial processes, instrumentation controls, and SCADA systems [4]. A graphical programming environment called "LabVIEW" is utilized for real-time data processing, display, and acquisition. The created hardware has an advantage over large, modern DAQ systems since it is inexpensive, portable, compact, and dependable even at high rates [5]. In terms of computer peripherals, the USB has become a ubiquitous technology, hardware's features, benefits, and drawbacks are examined. The virtual instruments, or LabVIEW software tools, created to communicate with the USB device are shown [6].

IMPLEMENTATION

The first step is to design the signal conditioning to amplifier the input from thermocouple/RTD. The cold junction compensation, frequency measuring, current measuring, subtractor, multiplexer, ADC block, timing and control unit, LCD interface circuits, microcontroller card and computer are used. The complete schematic of this card is shown in Figure 3 and Figure 4 shows schematic of USB microcontroller development board. Flow Chart of the Software is shown in flow chart 1. The program is divided into different .C (Source) and .H (Hex) files. Flow Charts for different routines are as follows. The function initializes different routines, acquires analog data, convert to digital, read data and manipulate data. Then it maintains USB connection and performs background process continuously until stopped. Memory Usage Map: (.mum file)

- Program space-13Fh (4415) of 8000h bytes (13.5%)
- Internal Data - 42h (66) of 100h bytes (25.8%)
- External Data - 00h (0) of 400h bytes (0.0%)

This includes initialization functions named Initialize RTOs, Initialize APPs and Initialize LCD. Each flow chart is shown in the form of functions, so after completion of function RETURN means to return to called function. The function basically deals with maintaining the USB connection of device to host. It is called frequently for keeping connection constantly. The function is called by main routine every time it is executed.

RESULT& DISCUSSION

The figure 5, 6 and 7 are showing active GUI, USB view window and image of implementation respectively. HI TIDE compiler generates .mum file which gives memory usage information of *hex* file generated from source code.

USB speed

Each transfer takes place in 500 μ sec which consists of 16 bytes of data in buffer i.e. 256 kbps is achieved. This rate can be increased to Mbps by setting the registers accordingly. Four channels with their digital display, system time & date and bytes received at instances are shown in front panel GUI with trend.

CONCLUSION

Several points are highlighted apart from novelty:

- The AT89C5131, an 8-bit CPU, performs well with a full-speed USB interface.
- Suspend resume management is implemented to optimize power consumption.
- It is flexible due to its plug and play compatibility.
- A sample rate of 500 samples per second per channel is achieved.





FUTURE SCOPE OF WORK

To make designed system more flexible and low cost with better performance, USB supported high end controller can be utilised and compact card can be developed for plug and play functionality.

REFERENCES

1. Wang, Hong Min, et al. "LabVIEW-based data acquisition system design." *Proceedings of 2012 International Conference on Measurement, Information and Control*. Vol. 2. IEEE, 2012.
2. Mujaahid, Faaris, et al. "Development of Data Acquisition System Using LabVIEW-based Interface for Aircraft Application." *Journal of Electrical Technology UMY* 2.3 (2018): 111-115.
3. Du, Jingyi, Wentao Li, and Jinbao Guo. "Design of LabVIEW based general data acquisition system." *2017 IEEE 2nd Information Technology, Networking, Electronic and Automation Control Conference (ITNEC)*. IEEE, 2017.
4. Fairs, Dhiya Mahdi, and Kasim Abdullah Ahmed. "USB Data Acquisition Using Peripheral Interface Control Microcontroller." *Tikrit J. Eng. Sci* 20.3 (2013): 10-21.
5. Pranav, Parmar, Pinky J. Brahmabhatt, and U. S. H. Rao. "USB based high speed data acquisition system." *2015 5th Nirma University International Conference on Engineering (NUiCONE)*. IEEE, 2015.
6. Litwhiler, Dale, and Terrance Lovell. "USB data acquisition units provide new measurement and control options for engineering technology students." *2005 Annual Conference*. 2005.

Table 1: Comparison of various interface standards

Interface	Format	No. of Devices (max)	Distance (Max, feet)	Speed (Max, bits/sec)
USB	Asynchronous serial	127	16 (up to 96 ft. with 5 hubs)	1.5M, 12M, 480M
RS-232 (EIA/TIA-232)	Asynchronous serial	2	50-100	20k
RS-485 (TIA/EIA-485)	Asynchronous serial	32-unit loads	4000	10M
IEEE-488 (GPIB)	Parallel	15	60	8M
PC	Synchronous serial	40	18	3.4M
IEEE-1394b	Serial	64	300	3.2G
Ethernet	Serial	1024	1600	10G

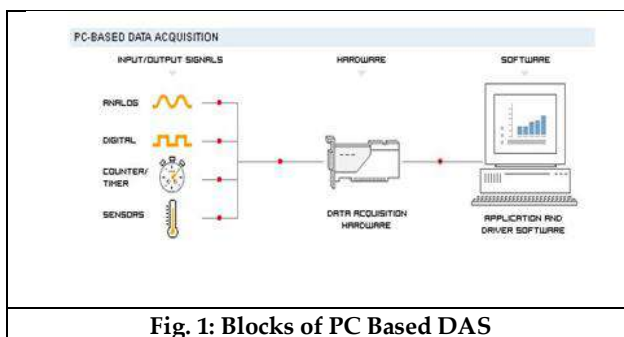


Fig. 1: Blocks of PC Based DAS

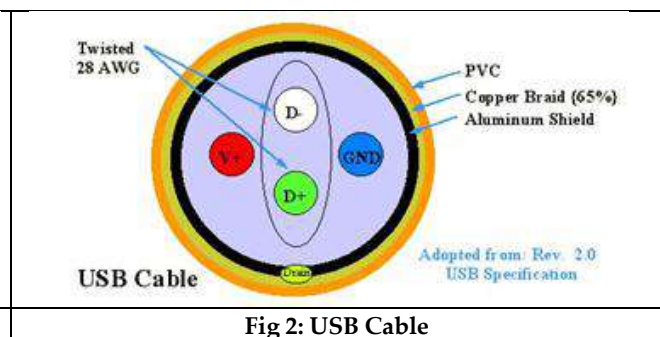
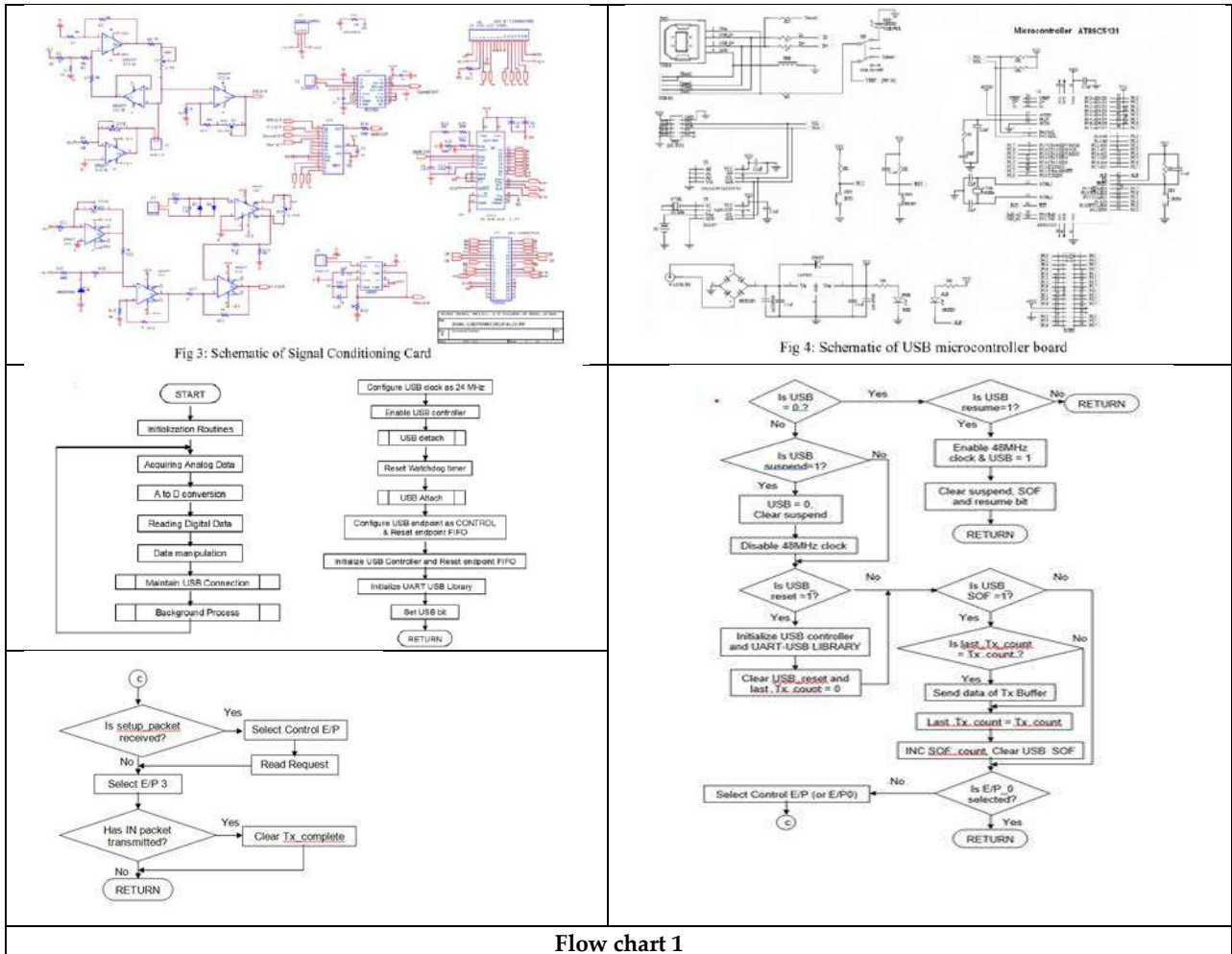


Fig 2: USB Cable





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Flow chart 1





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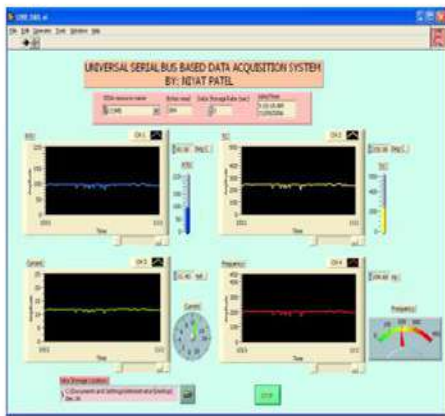


Fig 5: Active GUI

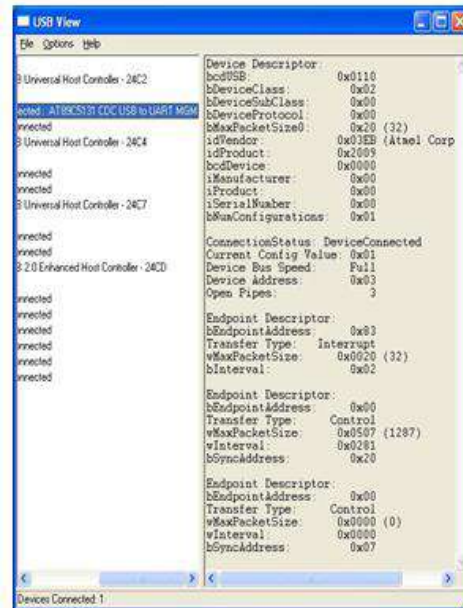


Fig 6: USB View Windows

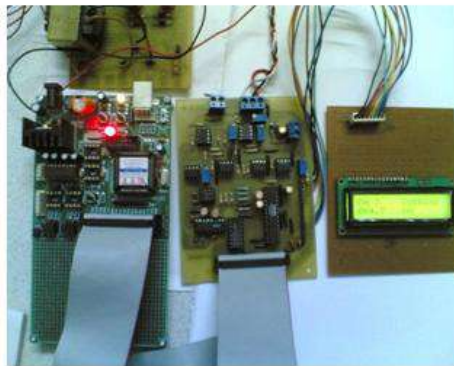


Fig 7: Implementation Image





Curcumin Encapsulated Nanoscale Chitosan– A Potent Outcome

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ABSTRACT

Cost effective drugs with high reliability is the most significant requirement in the field of biomedical engineering. The remedies to all human pathogens were occurring in nature, since the measures taking to seek the treatment is still in progress to provide better outcome. Here the review paper discusses the inbuilt properties of biopolymer chitosan and golden spice curcumin, and how its nanosized formulation enhances the application in various fields. Chitosan is a biodegradable polymer obtained from sea food industry waste having enormous bioactivity. Same way the curcumin is an active compound being separate from natural turmeric. In separately, chitosan is being utilized as provision in agriculture, medicine in pharmaceuticals and in the water purification systems. Curcumin is absolutely used in medical industries. Thus, chitosan-based drug delivery of curcumin with confinement in nano range size can be used as a new therapeutic to human pathogens.

Keywords: chitosan, polymer, curcumin, pathogens, applications





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INTRODUCTION

Nowadays biopolymers triggered great interest due to its usage as renewable sources for material engineering [1], [2]. By exploring techniques to preserve the polymer chain as much as possible, the biopolymers are sought as ideal precursors for high end functional material. Such biopolymers are synthesized by processing the exoskeletons of certain living organisms; they are greatly biodegradable and nontoxic unlike the synthetic polymers [3], [4]. Chitosan is such biopolymer of great industrial and biotechnological interest because of its abundant source, being compatible and reactive to enzymes in body, defining it as the active component delivery system [5]. Seafood waste is a potential source of raw material for chitin and chitosan extraction [6] with high benefits and can be used to produce the compounds [7]. However, it is a natural resource with high physical and chemical variability, the properties of chitin and chitosan have direct impact on their applications [8], [9]. Due to the difficulty in processing and reuse of waste form fishing industry, the significant percentage of biomass is discarded directly in the environment without undergoing any previous treatment [10]. Chitosan is a biomaterial which has the biological properties of biocompatibility, biodegradability and non-toxicity. This, chitosan is the only polycation in nature and its charge density depends on the degree of deacetylation and pH. Chitosan is soluble over a wide range of pH from acidic to basic and it depends on the degree of deacetylation and molecular weight. The chitosan with high molecular weight is only soluble in acidic aqueous solvents, even they have high degree of acetylation. This contraction in solubility has hindered chitosan application in many fields. Improved chitosan can be used as a therapeutic agent because it has antibacterial and antifungal characteristics, making it attention grabbing for applications in medicine, agriculture, food packing, cosmetics, water purification and textile industries [11]–[13]. In the extraction process, features molecular weight, degree of deacetylation, degree of purity, viscosity and crystallinity [14]. Indeed, high molecular weight biopolymers attribute improved mechanical properties and glass transition temperature [15], [16]. Despite its high added significant applications, chitin remains a largely underutilized biomass waste; there is thus a dare need to develop a simpler method of extractions, and methods able to afford a broader range of products which are needed to implement the shell biorefinery theorized [17]. Such one method is seeking to reduce energy, chemical and solvent input for improved sustainability, while being safe. Therefore, many studies are pursued to improve the aqueous solubility of chitosan. The different pharmaceuticals approach to have the potential of solubility, formulation processing, and the overall delivery of hydrophobic drugs [18]. This review focuses on possibilities utilized for chitosan-based curcumin particles in various applications.

HISTORY

Natural Polymer – CHITOSAN

In 1811, the research on chitin isolation and characterisation began by the French chemist Henri Braconnot, in fungal species like mushroom which were subjected to an aqueous alkali treatment. Lassaigne in 1843 conducted research from exoskeletons of the species *Bombyx mori* (Silk worm), in which he demonstrated the presence of nitrogen in the structure of chitin. Late in 1859 chitosan was discovered by treating chitin with Potassium Hydroxide in high temperature. In 1878, Ledderhose suggested the presence of glycosamine and acetic acid in chitin but only in 1894, Glison confirmed the presence of glucosamine units. Still, in 1894, the German Felix Hoppe-Seyler named the compound as Chitosan and in 1950 the chemical structure of chitosan was formed [19]. The first production reports of Chitosan were appearing in 1970 in United states and Japan. By 1986, Japan has fifteen industries actively working to produce chitin and chitosan commercially. In chitosan production Japan and the United States are outstanding and having great interest in the research of this natural polysaccharide in the variety of chitosan applications, being economically benefitable and sustainable [20]. Chitin is a natural polymer having high crystalline structure that is nitrogenous and white coloured. It is the second most abundant polysaccharide in nature next to cellulose having much bioactive ability. It is chemically composed of N-acetyl-2-amino-2-deoxy-D-glucose units joined by glycosidic bonds ($\beta 1 \rightarrow 4$) forming linear chain with some of the deacetylated monomers thus the chitin transforms to chitosan. It exchange ions while soluble with organic acids and diluted minerals [21], [22].





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Golden Spice – CURCUMIN

Natural derivatives from the plant sources always have a significant and promising role in pharmaceuticals in terms of therapeutic effects and biological activities. In such the golden spice – Turmeric has beneficial against the molecular, cellular, animal and human pathogens. Almost two centuries ago, Vogel and Pelletier reported the isolation of “yellow colouring matter” from the rhizomes of *curcuma longa* (turmeric) and named as curcumin. Curcumin is the mixture of resin and turmeric oil. Vogel in 1842, obtained the pure form of curcumin[23]. Later chemists in 1910 identified the chemical structure of curcumin as diferuloylmethane or 1,6- heptadiene-3,5–dione-1, 7-bis (4-hydroxy-3- methoxyphenyl) -(1E,6E)[24]. A chemist named Srinivasan a separated and quantified the components of curcumin by column chromatography [25], [26]. Such curcumin obtained from the root of turmeric is non-toxic, bioactive agent having antibacterial and anti-oxidant properties has been utilized in traditional medicine.

CHITOSAN A BIOPOLYMER – ORIGIN

Natural polymer chitosan is found in the exoskeletons of squid, fish scales, shrimp shell, and some of insects like silk worm, beetles, cockroaches and funguses. Among all the sources, the polymer from sea food is a rich resource obtained from the waste of sea food industry. Chitosan from shrimp shell waste has 30 – 40% weight as shell[27]. Shrimps and prawns are considered as important aquaculture products due to its health benefits and most wanted food among people. Shrimp shell contains a higher amount of chitin which is an expensive component used in cosmetics, foods and pharmaceuticals. Production of chitosan within the country can reduce the dependency on importing this valuable raw material[28].

EXTRACTION TECHNIQUES

Chitosan a basic biopolymer which is comprised of one of monomer of glucose. In general, two different methods are known for the synthesis of chitosan from chitin in degree of deacetylation variations. The one method is solid chitin heterogeneous deacetylation and the other is preswollen chitin in homogeneous deacetylation under vacuum in an aqueous medium. For both the cases, concentrated alkali solutions and long-time processing are required for the deacetylation reaction which may vary depending on the heterogeneous or homogeneous conditions from 1 to nearly 80 hrs. In the preparation of chitosan from fishery waste materials which are hazard and toxic for environment is a simple practice. The typical production of chitosan from marine crustaceans generally consists of three basic steps: demineralization, deproteinization, and deacetylation. There is a possibility to produce both chitin and chitosan within the existing process. Therefore, researchers aimed at developing appropriate field support techniques for the huge commercial manufacture of chitin and chitosan from marine wastes. The quality and purity of chitin and chitosan were determined by some subjective and objective methods. Subjective methods included sensory analysis, whiteness, pulverizing property etc., and the objective methods included biochemical parameters, moisture content, reabsorption property and solubility[29].

CURCUMIN - A NATURAL SOURCE

Curcumin originates from the Indian spice turmeric (*curcumin longa*) a type of ginger. It is a potent anti-inflammatory agent that can reduce inflammation and plays a key role in the treatment of AD (Anno Domini)[30], [31]. Still turmeric is used in cuisines as a spice. In ayurveda, turmeric is taken for medicines. In traditional, turmeric has been used as a medicine to treat wounds, colds and infections, and as a natural colouring agent in preparing foods. A turmeric root contains only 2-5% of curcumin. Turmeric by nature consist of several active constituents isolated from the rhizome, structurally related curcuminoids, including curcumin as the most important and main bioactive compound. Besides curcuminoids ingredients including yellow pigment curcumin (diferuloylmethane; 1,7-bis(4-hydroxy-3-methoxy-phenyl)hepta-1,6-diene-3,5-dione), demethoxycurcumin (DMCur), bismethoxycurcumin (BDMCur), and cyclocurcumin (CCur) are present in turmeric [32].



**Annlin Bezy et al.,****SEPERATION OF BIOACTIVE CURCUMIN**

In 1815, the extraction and separation of active compound curcumin from the grounded turmeric was reported, but still the advanced and improved method is ongoing research[33]–[35]. The fresh turmeric was dried and grounded initially for Soxhlet extraction method. In Soxhlet apparatus the polar and non-polar solvents including acetone, ethanol, hexane, ethyl acetate, methanol etc can be preferred to extract. The extract is employed for column chromatography to separate the compound curcumin. Among the organic solvents employed ethanol is the highly preferred for curcumin extraction. The chlorinated solvent extraction being effective, is not used because of its non-acceptability in the food industry [36], [37]. Curcumin separation from turmeric constituents by column chromatography is done using silica gel to yield different fractions. The purification of the yielded curcumin can further be done by silica gel using chloroform/dichloromethane and ethanol/methanol mixtures as eluents [38]–[40]. High performance liquid chromatography (HPLC) technique is used for the detection and estimation of curcumin. The reverse phase C₁₈ columns are used as stationary phase and different gradients of solvents containing acetonitrile/water or chloroform/methanol can be employed as the mobile phase [41], [42]. The presence of curcumin is confirmed by using absorption detectors in the wavelength range from 350 to 450 nm in the UV region using a common detection wavelength in the range of 250 to 270 nm.

CHARACTERISTICS OF CHITOSAN

Chitosan is a cationic polysaccharide. It has drawn great attention in pharmaceuticals and medical applications, owing to its plenty availability and unique mucoadhesive[43]. The chitosan structure has amino group and it might be protonated providing solubility in dilute aqueous solutions[44]. The beneficial biological properties such as biocompatibility, biodegradability, non-toxicity and low immunogenicity[45]–[47]. The chitosan is insoluble in water, organic solvents, aqueous bases and it is soluble in acid such as acetic, nitric, hydrochloric, perchloric and phosphoric[48]. The haemostatic activity of chitosan is related to the positive charges. Due to its positive charges, chitosan interacts with the negative of cell membrane, helps to open the tight protein junction. Chitin polymorphism can be determined using X ray diffraction, where three crystalline structures α , β and γ are observed by unit size. The α -chitin is the most abundant form found in arthropod exoskeletons with anti-parallel polymeric chains, which favours the existence of numerous inter and intra hydrogen bonds. In β -chitin the disposition of chain is parallel and they are found in animals such as squids having flexibility and resistance. The γ -chitin show the combination of both chain positions [49], [50]. Functional properties of chitin and chitosan varies from product to product due to the season, quality of shell, species present, climate and by the whole processing method involved.

Physical properties

The chitin and chitosan are amorphous solids and almost insoluble in water. This is due to intermolecular hydrogen bonding, which forms between the neutral molecules of chitosan. Chitosan is a firm polymer due to hydrogen bonding in its molecular structure. Subsequently, it can be easily transformed into film with high mechanical strength. Chitosan is a weak polyelectrolyte, a poor anion exchanger. Therefore, it is likely to form films on negatively charged surfaces, and it also has the ability to chemically bind with fats, cholesterol, proteins and macromolecules [51], [52].

Chemical properties

Chitosan's cationic nature is due to the presence of amino and hydroxyl groups, which make it modifiable by including complexation, grafting, cross-linking and blending [53]. The aqueous solubility of chitosan depends upon the balance between electrostatic repulsion [54]. The degree of deacetylation plays a major role in molecular weight of chitosan. The lower deacetylation, higher the molecular weight, which results higher chemical stability and mechanical strength [55]. Furthermore, the properties of chitosan not only depends on the degree of deacetylation, but also on the distribution of the acetyl groups along the chain, the solvent concentration and the type of solvent[56], [57].



**Annlin Bezy et al.,****Biological properties**

Chitin derived biopolymer chitosan is non-toxic, biocompatible and biodegradable. They are amino polysaccharides having biological, physiological and pharmacological properties [58]. The prominent bioactivities include the promotion of wound healing, hemostatic activity, immune enhancement, mucoadhesion, eliciting biological responses and antimicrobial activity. Chitosan is also a promising supporting polymer for gene delivery, cell culture and tissue engineering. Chitin and chitosan as dietary fibre's exhibit hypolipidemic activity, as confirmed by the reduced cholesterol and triglyceride levels in blood plasma and liver of rats [59]. Chitosan was highly effective than chitin [60]; thus, chitosan's derivatives are important for medical field [61].

BIOACTIVE PROPERTIES OF CURCUMIN

Curcumin is a chemotherapeutic agent with antioxidant, anti-inflammatory, anti-proliferative, anti-cancer and anti-microbial effects. However, the potential of curcumin mentioned is limited by its hydrophobicity and poor availability [62]. Being curcumin as a strong anti-bacterial drug, it is valid to prevent the growth of several bacteria's including staphylococcus aureus and pseudomonas aeruginosa also it is a good candidate for treating inflammatory diseases [63]. Curcumin also possesses anti-amyloidogenic, anti-oxidative and metal chelating properties [64] having the potential neuroprotective effects [65], [66]. The combination of low solubility and poor availability negatively affects its biological efficiency [67]. Improving the poor biopharmaceutical properties of curcumin and to improve its aqueous solubility is the size confinement, that needed using nanotechnology [68]–[70]. The anticancer and radio protective effects of curcumin have been demonstrated on many types of tissues including skin, brain, colon, gastrointestinal, liver, lungs, pancreas, mammary glands, prostate, breast, blood and bone marrow [71]–[74]. In nature, curcumin is not only has the potential to prevent radiation damage with its antioxidant properties, but also initiate DNA repair processes in radiation damaged cells [75].

CURCUMIN – CHITOSAN ENCAPSULATION

Chitosan is a positively charged polymer with tendency to interact with negatively charged cell surface or enzymes in body [76]. These beneficial properties made chitosan to one of most popular biopolymers for the development of bioactive compounds delivery systems in a wide range of applications [77]. Due to the real fact that, the surface of all physiological membranes including intestine having negative surface charge can be easily interact with positively charged chitosan, thus proven to enhance the properties and making them very attractive [78], [79]. Curcumin as a natural photosensitizer is active against cancer cells. Chitosan's destabilization in excessive heat, light and alkaline conditions and poor water solubility had led to decrease its bioavailability [80], [81]. Thus, to make bioavailable for a long time and to increase its bioactivity, chitosan-carboxymethyl cellulose particle encapsulated with curcumin was considered. Encapsulation includes the immobilization of a particular compound in a material that makes coating or got dispersed. Curcumin a traditional drug having high anti-oxidant, antibacterial activity will promote for tissue engineering like tissue regeneration by tissue remodelling, new tissue formation, granulation and collagen deposition. The photosensitive property of curcumin also makes it to be a suitable carrier enabling penetration to skin effectively. Some of mediated drug delivery systems having wound healing benefits are polymer – curcumin nanoparticles [82], [83], polymer – curcumin nano emulsion gel [84], [85], self-assembled nanogels [86], and hydrogels [87], [88]. Still research is under process to develop the scaffolds in the form of sponges, films and nanofibers [89]–[91]. Encapsulation can improve the disadvantages and difficulties in low aqueous solubility and protect a molecule from degradation or loss of functionality due to the effects of photons, oxygen, pH and moisture.

ACTIVITIES OF CURCUMIN-CHITOSAN IN NANO SCALE

Nano sized resources have improved or unpredicted properties than bulk materials. The organic and inorganic particles size can be varied by numerous preparation routes like top-down, bottom-up, crosslinking, microbial methods. Nanoparticles by any of routes have been investigated intensely to put in applications in the field of electronics, textiles, medicine, agriculture. In medical area, the nanosized formulation shields the loaded drug from degradation by pH and increases its half-life. Curcumin as a natural therapeutic agent consists of two symmetric o-



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methoxy phenolic groups attached to α and β -unsaturated β -diketone which have potential photochemical properties. In vitro and in vivo analysis results that nanocurcumin loaded with a nano carrier having more health-span-promoting features than traditional or native curcumin. The water solubility and bioavailability of curcumin compound can be improved through nanoencapsulation with lipids, polymeric nanoparticles, nanogels, dendrimers and conjugating to some metal oxide nanoparticles[92]. Nanoencapsulation compound act as a high potential carrier of bioactive substances due to their subcellular size, allowing relatively higher intracellular intake, improved stability and protection of reliable substances against degradation [93]–[95]. Particle size plays a main role drug delivery of all human pathogens. As by reviewing many reports, the nanosized particles has relatively better intercellular bonding comparing to micron sized particles [96]. In chitosan nanoparticles the variety hydrophilic and hydrophobic drugs can be included during the synthesis process as nanoparticle. The loading efficiency of the drug may depend on its physicochemical features and the adopted synthesis methods of micro and nano particle systems [97], [98]. Solubility of curcumin can be improved by developing nano formulation using chitosan as biodegradable and biocompatible polymer, having the ability to encapsulate curcumin and improve its therapeutic effect [99]. Curcumin nanoparticles exhibit superior drug delivery, enhanced transdermal permeation and superior cell viability [100]. Covalent linkage of curcumin and chitosan to produce chitosan -curcumin polymer has (1) improved curcumin stability for more than 1 month at above freezing and ambient temperatures, (2) solubility improvement in aqueous medium, (3) improved bioavailability, (4) controlled release of conjugated curcumin, (5) curcumin's anti-oxidant can be retrieved through ester hydrolysis[74], [101]. When nano formulation is considered, the biopolymers are the best choice for better treatments. Ionic gelation, solvent evaporation, complex coacervation, emulsion cross linking, spray drying, solvent displacement is the most popularly considered method for the preparation of polymer-based nanoparticles [102]. Among the mentioned methods, ionic gelation and complex coacervation are alike and ideal for improved biostability of drugs [103]. However, curcumin's bioactivities are hindered due its lower solubility, lower cellular uptake and bioavailability, but the progress in nanotechnology has disabled all the hinderances, thus polymeric nanoparticles can be used to encapsulate curcumin. By these, the curcumin's limitations can overcome and get improved bioavailability, target disease cells, prevent from degradation or metabolism, thus increases its therapeutic potential [104].

APPLICATIONS OF NANO CHITOSAN-CURCUMIN COMPOUND

In current scenario new technological approaches are needed to improve human lives and the environment. Researchers broadly investigated the chitosan nanoparticles for numerous applications in medicine, water treatment, agriculture and pharmaceuticals. Its broad spectrum of properties such as cationic biopolymer, capable of forming gels, pH range, enzymatic interaction chitosan material reveals great industrial interest [105]. Chitin and chitosan-based nanomaterials are used as a carriers of cosmetic manufacturing ingredients such as chitin nano fibrils face masks capable of releasing active compounds at different doses with time, thus can be used as anti-bacterial, anti-inflammatory, sunscreen, anti-aging cosmetics [106]. Chitosan alone is not suitable for blood interacting drugs, inspite of its biocompatibility. Due this blood coagulating property, chitosan is a desirable material for haemostatic agent. This haemostatic activity of chitosan with the mechanism of action as a coagulant is used for developing medical bandages which control bleeding during surgery. The haemostatic mechanism induced from chitosan is independent of traditional blood coagulation cascade[107]–[110]. Chitosan in target to antimicrobial action of bacteria, it easily gets bind and inhibits the transport of nutrients to cells [20], [111], [112].Molecular weight and viscosity of chitosan have to be low; hence high surface charge and smaller particle size can be achieved while confining to nano scale, thus penetration of drugs to skin will be effective[113].Microwave method of low molecular weight chitosan-curcumin nanoparticles hold effective in skin manifestation treatment, through the curcumin reaction with skin [114]. Chitosan also considered for fat binder, wound healing, hypocholesterolaemia effect treatments [115].

Medicine and Pharmaceutics

Chitosan nanoparticles allows encapsulation and chain grafting of the drugs and active constituents. Remarkable features such as reducing the damage of non-targeted tissue or cells and preventing enzymatic degradation of drugs



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[116] makes their use in drug delivery, cancer treatment and biological imaging and diagnosis [117]. Curcumin loaded chitosan nanoparticles reduces the progression of staphylococcus aureus and pseudomonas aeruginosa bacterial infection in skin. Curcumin alone or chitosan – TPP will not inhibit bacterial infection. The antimicrobial action of curcumin loaded chitosan nanoparticles significantly high [63]. Skin repair treatment can effectively be achieved by curcumin and chitosan nanoparticles. In wound healing, existing fibrous mats are difficult to fix into wound; also, not able fit the shape of irregular wounds. The availing soft hydrogels fix to the irregular wound; still its poor permeability affects the supply of nutrients like oxygen during skin repair [118], [119].

Agriculture

In agriculture chitosan nanoparticles is a necessary compound helps to increase the sustainable and agro friendly agrochemicals like fertilizers and pesticides. Similar as in medical field, chitosan nanoparticles act as a nano carrier to enhance the stability and to create controlled release [120], [121]. Through these effects, agrochemicals can be feed in low quantity, hence contamination risk to the environment and other toxic effects to non-targeted organisms and species were decreased [122], [123]. In food packing the polymer-based antioxidant compound enhances the food freshness. The chitosan film can be improved by incorporating curcumin an antioxidant agent as a source of phenolic compounds [124]. The non-thermal technology is used to prevent food from microbial contamination, extend shelf life and ensure food safety. The light absorption properties of curcumin results to get a decreased light transmittance of composite film with good transparency [125].

Water Treatment

The lack of a cost effective, sustainable, effective absorbent to replace the activated carbon has improved the bio-based alternatives [126]. Chitosan with functional amino and hydroxyl group and curcumin in nano size helps for the removal of a wide range of pollutants like heavy metals, dyes, impurities and pesticides [127]. These nanoparticles exhibit higher capacity than conventionally used macro and micro sized purification sponge sorbents due to their higher surface area [128].

CONCLUSION

Curcumin loaded chitosan nanoparticles with potential drug delivery systems and applied as an approach to activate anti-bacterial systems. The higher cytotoxicity effect of curcumin loaded chitosan nano range particles may be due to their higher cellular uptake as compared to curcumin separately. Curcumin loaded nano formulations, therefore a promising compound in cancer therapy [129]. Chitosan is simply obtained from shrimp shell waste by a simple treatment and some reactions. Chitosan derivatives are relatively inexpensive for taking in haemostatic agents being fibrinogen-based treatments are expensive and infectious. The applicability of chitosan curcumin nanoparticles in pharmaceuticals and medicine can be efficient by the controlled release of drugs and stability in unaffected cells. The incorporation of curcumin chitosan nanosized compound is an enriching feed to stimulate immunity and boost the diet formulations.

REFERENCES

1. L. Summerton, H. F. Sneddon, L. C. Jones, and J. H. Clark, *Green and Sustainable Medicinal Chemistry*. Cambridge: Royal Society of Chemistry, 2016. doi: 10.1039/9781782625940.
2. T. Di Nardo, C. Hadad, A. Nguyen Van Nhien, and A. Moores, "Synthesis of high molecular weight chitosan from chitin by mechanochemistry and aging," *Green Chem.*, vol. 21, no. 12, pp. 3276–3285, 2019, doi: 10.1039/C9GC00304E.





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3. A. V. Samrot, U. Burman, S. A. Philip, S. N, and K. Chandrasekaran, "Synthesis of curcumin loaded polymeric nanoparticles from crab shell derived chitosan for drug delivery," *Informatics Med. Unlocked*, vol. 10, pp. 159–182, 2018, doi: 10.1016/j.imu.2017.12.010.
4. X. Z. Tang, P. Kumar, S. Alavi, and K. P. Sandeep, "Recent Advances in Biopolymers and Biopolymer-Based Nanocomposites for Food Packaging Materials," *Crit. Rev. Food Sci. Nutr.*, vol. 52, no. 5, pp. 426–442, May 2012, doi: 10.1080/10408398.2010.500508.
5. J. Yang et al., "pH-Sensitive Chitosan–Sodium Phytate Core–Shell Hollow Beads and Nanocapsules for the Encapsulation of Active Ingredients," *J. Agric. Food Chem.*, vol. 67, no. 10, pp. 2894–2905, Mar. 2019, doi: 10.1021/acs.jafc.8b03919.
6. C. Casadidio, D. V. Peregrina, M. R. Gigliobianco, S. Deng, R. Censi, and P. Di Martino, "Chitin and Chitosans: Characteristics, Eco-Friendly Processes, and Applications in Cosmetic Science," *Mar. Drugs*, vol. 17, no. 6, p. 369, Jun. 2019, doi: 10.3390/md17060369.
7. B. Mohanty, U. Mohanty, S. S. Pattanaik, A. Panda, and A. K. Jena, "FUTURE PROSPECTS AND TRENDS FOR EFFECTIVE UTILIZATION OF FISH PROCESSING WASTES IN INDIA," *Innov. Farming*, vol. 3, no. 1, pp. 1–5, Mar. 2018, [Online]. Available: <http://www.innovativefarming.in/index.php/IF/article/view/26>
8. V. P. Santos, N. S. S. Marques, P. C. S. V. Maia, M. A. B. de Lima, L. de O. Franco, and G. M. de Campos-Takaki, "Seafood Waste as Attractive Source of Chitin and Chitosan Production and Their Applications," *Int. J. Mol. Sci.*, vol. 21, no. 12, p. 4290, Jun. 2020, doi: 10.3390/ijms21124290.
9. E. B. Ibitoye, I. H. Lokman, M. N. M. Hezmee, Y. M. Goh, A. B. Z. Zuki, and A. A. Jimoh, "Extraction and physicochemical characterization of chitin and chitosan isolated from house cricket," *Biomed. Mater.*, vol. 13, no. 2, p. 025009, Jan. 2018, doi: 10.1088/1748-605X/aa9dde.
10. V. B. Nguyen and S.-L. Wang, "Production of potent antidiabetic compounds from shrimp head powder via *Paenibacillus* conversion," *Process Biochem.*, vol. 76, pp. 18–24, Jan. 2019, doi: 10.1016/j.procbio.2018.11.004.
11. H. Srinivasan, V. Kanayairam, and R. Ravichandran, "Chitin and chitosan preparation from shrimp shells *Penaeus monodon* and its human ovarian cancer cell line, PA-1," *Int. J. Biol. Macromol.*, vol. 107, pp. 662–667, Feb. 2018, doi: 10.1016/j.ijbiomac.2017.09.035.
12. H. Wu et al., "Regenerated chitin fibers reinforced with bacterial cellulose nanocrystals as suture biomaterials," *Carbohydr. Polym.*, vol. 180, pp. 304–313, Jan. 2018, doi: 10.1016/j.carbpol.2017.10.022.
13. E. Medina, N. Caro, L. Abugoch, A. Gamboa, M. Díaz-Dosque, and C. Tapia, "Chitosan thymol nanoparticles improve the antimicrobial effect and the water vapour barrier of chitosan-quinoa protein films," *J. Food Eng.*, vol. 240, pp. 191–198, Jan. 2019, doi: 10.1016/j.jfoodeng.2018.07.023.
14. H. El Knidri, R. Belaabed, A. Addaou, A. Laajeb, and A. Lahsini, "Extraction, chemical modification and characterization of chitin and chitosan," *Int. J. Biol. Macromol.*, vol. 120, pp. 1181–1189, Dec. 2018, doi: 10.1016/j.ijbiomac.2018.08.139.
15. L. Bekale, D. Agudelo, and H. A. Tajmir-Riahi, "Effect of polymer molecular weight on chitosan–protein interaction," *Colloids Surfaces B Biointerfaces*, vol. 125, pp. 309–317, Jan. 2015, doi: 10.1016/j.colsurfb.2014.11.037.
16. A. Sionkowska, A. Planecka, K. Lewandowska, B. Kaczmarek-Szczepańska, and P. Szarszewska, "Influence of UV-irradiation on molecular weight of chitosan," *Prog. Chem. Appl. Chitin Its Deriv.*, vol. XVIII, p. 21, Jul. 2013.
17. X. Chen, H. Yang, and N. Yan, "Shell Biorefinery: Dream or Reality?," *Chem. - A Eur. J.*, vol. 22, no. 38, pp. 13402–13421, Sep. 2016, doi: 10.1002/chem.201602389.
18. M. Saheb, N. Fereydouni, S. Nemati, G. E. Barreto, T. P. Johnston, and A. Sahebkar, "Chitosan-based delivery systems for curcumin: A review of pharmacodynamic and pharmacokinetic aspects," *J. Cell. Physiol.*, vol. 234, no. 8, pp. 12325–12340, Aug. 2019, doi: 10.1002/jcp.28024.
19. D. (Berlin U. of T. Knorr Berlin Germany), "Recovery and utilization of chitin and chitosan in food processing waste management," *Food technology (USA)*, vol. v. 45.
20. N. R. Sudarshan, D. G. Hoover, and D. Knorr, "Antibacterial action of chitosan," *Food Biotechnol.*, vol. 6, no. 3, pp. 257–272, Jan. 1992, doi: 10.1080/08905439209549838.
21. G. Dilarri, C. R. Mendes, and A. O. Martins, "Síntese de biofilmes de Quitosana reticulados com Tripolifosfato atuando como agente quelante na fixação de nanopartículas de Prata," *Ciência Eng.*, vol. 25, no. 1, pp. 97–103, Oct. 2016, doi: 10.14393/19834071.2016.27704.





Annlin Bezy et al.,

22. P. F. P. Barbosa, L. R. Cumba, R. D. A. Andrade, and D. R. do Carmo, "Chemical Modifications of Cyclodextrin and Chitosan for Biological and Environmental Applications: Metals and Organic Pollutants Adsorption and Removal," *J. Polym. Environ.*, vol. 27, no. 6, pp. 1352–1366, Jun. 2019, doi: 10.1007/s10924-019-01434-x.
23. L. Makgoo and Z. Mbita, "Germicidal and Antineoplastic Activities of Curcumin and Curcumin-Derived Nanoparticles," in *Antimicrobial and Pharmacological Aspects of Curcumin [Working Title]*, IntechOpen, 2022. doi: 10.5772/intechopen.103076.
24. S. Ilkar Erdagi and C. Uyanik, "Biological evaluation of bioavailable amphiphilic polymeric conjugate based-on natural products: diosgenin and curcumin," *Int. J. Polym. Mater. Polym. Biomater.*, vol. 69, no. 2, pp. 73–84, Jan. 2020, doi: 10.1080/00914037.2018.1539989.
25. K. R. Srinivasan, "A CHROMATOGRAPHIC STUDY OF THE CURCUMINOIDS IN *CURCUMA LONGA* , L.," *J. Pharm. Pharmacol.*, vol. 5, no. 1, pp. 448–457, Apr. 2011, doi: 10.1111/j.2042-7158.1953.tb14007.x.
26. S. C. Gupta, S. Patchva, W. Koh, and B. B. Aggarwal, "Discovery of curcumin, a component of golden spice, and its miraculous biological activities," *Clin. Exp. Pharmacol. Physiol.*, vol. 39, no. 3, pp. 283–299, Mar. 2012, doi: 10.1111/j.1440-1681.2011.05648.x.
27. S. Begum, . K. I., . H. A., and . M. Z. I., "Solar Drying as an Option for Shrimp Processing Biowaste in Khulna District-Southwest Bangladesh," *J. Appl. Sci.*, vol. 6, no. 6, pp. 1302–1306, Mar. 2006, doi: 10.3923/jas.2006.1302.1306.
28. S. Islam, M. Khan, and A. N. Alam, "Production of chitin and chitosan from shrimp shell wastes," *J. Bangladesh Agric. Univ.*, vol. 14, no. 2, pp. 253–259, May 2017, doi: 10.3329/jbau.v14i2.32701.
29. F. Cheng, J. Gao, L. Wang, and X. Hu, "Composite chitosan/poly(ethylene oxide) electrospun nanofibrous mats as novel wound dressing matrixes for the controlled release of drugs," *J. Appl. Polym. Sci.*, vol. 132, no. 24, p. n/a-n/a, Jun. 2015, doi: 10.1002/app.42060.
30. R. Yang, Y. Zheng, Q. Wang, and L. Zhao, "Curcumin-loaded chitosan–bovine serum albumin nanoparticles potentially enhanced A β 42 phagocytosis and modulated macrophage polarization in Alzheimer's disease," *Nanoscale Res. Lett.*, vol. 13, no. 1, p. 330, Dec. 2018, doi: 10.1186/s11671-018-2759-z.
31. S. C. Gupta, B. Sung, J. H. Kim, S. Prasad, S. Li, and B. B. Aggarwal, "Multitargeting by turmeric, the golden spice: From kitchen to clinic," *Mol. Nutr. Food Res.*, vol. 57, no. 9, pp. 1510–1528, Sep. 2013, doi: 10.1002/mnfr.201100741.
32. R. Shanmugam et al., "Curcumin-Chitosan Nanocomposite Formulation Containing Pongamia pinnata-Mediated Silver Nanoparticles, Wound Pathogen Control, and Anti-Inflammatory Potential," *Biomed Res. Int.*, vol. 2021, pp. 1–10, Dec. 2021, doi: 10.1155/2021/3091587.
33. K. Priyadarsini, "The Chemistry of Curcumin: From Extraction to Therapeutic Agent," *Molecules*, vol. 19, no. 12, pp. 20091–20112, Dec. 2014, doi: 10.3390/molecules191220091.
34. K. J. Lee, H. J. Yang, S. W. Jeong, and J. Y. Ma, "Solid-Phase Extraction of Curcuminoid from Turmeric Using Physical Process Method," *Korean Journal of Pharmacognosy*, vol. v. 43, no. 3. pp. 250–256, 2012.
35. V. P. Paulucci, R. O. Couto, C. C. C. Teixeira, and L. A. P. Freitas, "Optimization of the extraction of curcumin from *Curcuma longa* rhizomes," *Rev. Bras. Farmacogn.*, vol. 23, no. 1, pp. 94–100, Jan. 2013, doi: 10.1590/S0102-695X2012005000117.
36. M. Li, M. O. Ngadi, and Y. Ma, "Optimisation of pulsed ultrasonic and microwave-assisted extraction for curcuminoids by response surface methodology and kinetic study," *Food Chem.*, vol. 165, pp. 29–34, Dec. 2014, doi: 10.1016/j.foodchem.2014.03.115.
37. N. Kurmudle, L. D. Kagliwal, S. B. Bankar, and R. S. Singhal, "Enzyme-assisted extraction for enhanced yields of turmeric oleoresin and its constituents," *Food Biosci.*, vol. 3, pp. 36–41, Sep. 2013, doi: 10.1016/j.fbio.2013.06.001.
38. M. Paramasivam, R. Poi, H. Banerjee, and A. Bandyopadhyay, "High-performance thin layer chromatographic method for quantitative determination of curcuminoids in *Curcuma longa* germplasm," *Food Chem.*, vol. 113, no. 2, pp. 640–644, Mar. 2009, doi: 10.1016/j.foodchem.2008.07.051.





Annlin Bezy et al.,

39. T. Esatbeyoglu, P. Huebbe, I. M. A. Ernst, D. Chin, A. E. Wagner, and G. Rimbach, "Curcumin-From Molecule to Biological Function," *Angew. Chemie Int. Ed.*, vol. 51, no. 22, pp. 5308–5332, May 2012, doi: 10.1002/anie.201107724.
40. G. Gryniewicz and P. Ślifirski, "Curcumin and curcuminoids in quest for medicinal status.," *Acta Biochim. Pol.*, vol. 59, no. 2, pp. 201–12, 2012.
41. K. J. Lee, Y. S. Kim, P. M. Jung, and J. Y. Ma, "Optimization of the Conditions for the Analysis of Curcumin and a Related Compound in *Curcuma longa* with Mobile-Phase Composition and Column Temperature via RP-HPLC," *Asian J. Chem.*, vol. 25, no. 11, pp. 6306–6310, 2013, doi: 10.14233/ajchem.2013.14471.
42. I. Ali, A. Haque, and K. Saleem, "Separation and identification of curcuminoids in turmeric powder by HPLC using phenyl column," *Anal. Methods*, vol. 6, no. 8, pp. 2526–2536, 2014, doi: 10.1039/C3AY41987H.
43. P. Dutta, J. Dutta, and V. Tripathi, "Chitin and chitosan: Chemistry, properties and applications," *J Sci Indus Res*, vol. 63, Nov. 2003.
44. S. Samad, M. Masum, and M. Moniruzzaman, "Preparation and Characterization of Chitosan from Shrimp shell waste," *IJSER*, vol. 6, Jul. 2015.
45. O. Felt, P. Buri, and R. Gurny, "Chitosan: A Unique Polysaccharide for Drug Delivery," *Drug Dev. Ind. Pharm.*, vol. 24, no. 11, pp. 979–993, Jan. 1998, doi: 10.3109/03639049809089942.
46. L. Ilium, "Chitosan and its use as a pharmaceutical excipient," *Pharm. Res.*, vol. 15, no. 9, pp. 1326–1331, 1998, doi: 10.1023/A:1011929016601.
47. M. N. V. R. Kumar, R. A. A. Muzzarelli, C. Muzzarelli, H. Sashiwa, and A. J. Domb, "Chitosan Chemistry and Pharmaceutical Perspectives," *Chem. Rev.*, vol. 104, no. 12, pp. 6017–6084, Dec. 2004, doi: 10.1021/cr030441b.
48. E. S. de Alvarenga, "Characterization and Properties of Chitosan," in *Biotechnology of Biopolymers*, InTech, 2011. doi: 10.5772/17020.
49. M. G. Mehrabani et al., "Chitin/silk fibroin/TiO₂ bio-nanocomposite as a biocompatible wound dressing bandage with strong antimicrobial activity," *Int. J. Biol. Macromol.*, vol. 116, pp. 966–976, Sep. 2018, doi: 10.1016/j.ijbiomac.2018.05.102.
50. G. Ru et al., "Inverse solubility of chitin/chitosan in aqueous alkali solvents at low temperature," *Carbohydr. Polym.*, vol. 206, pp. 487–492, Feb. 2019, doi: 10.1016/j.carbpol.2018.11.016.
51. Q. Li, E. T. Dunn, E. W. Grandmaison, and M. F. A. Goosen, "Applications and Properties of Chitosan," *J. Bioact. Compat. Polym.*, vol. 7, no. 4, pp. 370–397, Oct. 1992, doi: 10.1177/088391159200700406.
52. A. Rajeswari, S. Gopi, E. Jackcina Stobel Christy, K. Jayaraj, and A. Pius, "Current research on the blends of chitosan as new biomaterials," in *Handbook of Chitin and Chitosan*, Elsevier, 2020, pp. 247–283. doi: 10.1016/B978-0-12-817970-3.00009-2.
53. A. Denuziere, D. Ferrier, O. Damour, and A. Domard, "Chitosan–chondroitin sulfate and chitosan–hyaluronate polyelectrolyte complexes: biological properties," *Biomaterials*, vol. 19, no. 14, pp. 1275–1285, Jul. 1998, doi: 10.1016/S0142-9612(98)00036-2.
54. H. Martín-López et al., "Structural and Physicochemical Characterization of Chitosan Obtained by UAE and Its Effect on the Growth Inhibition of *Pythium ultimum*," *Agriculture*, vol. 10, no. 10, p. 464, Oct. 2020, doi: 10.3390/agriculture10100464.
55. K. Nagasawa, Y. Tohira, Y. Inoue, and N. Tanoura, "Reaction between carbohydrates and sulfuric acid," *Carbohydr. Res.*, vol. 18, no. 1, pp. 95–102, May 1971, doi: 10.1016/S0008-6215(00)80261-X.
56. N. Kubota and Y. Eguchi, "Facile Preparation of Water-Soluble N-Acetylated Chitosan and Molecular Weight Dependence of Its Water-Solubility," *Polym. J.*, vol. 29, no. 2, pp. 123–127, Feb. 1997, doi: 10.1295/polymj.29.123.
57. S. Aiba, "Studies on chitosan: 3. Evidence for the presence of random and block copolymer structures in partially N-acetylated chitosans," *Int. J. Biol. Macromol.*, vol. 13, no. 1, pp. 40–44, Feb. 1991, doi: 10.1016/0141-8130(91)90008-I.
58. M. Dai et al., "Chitosan-Alginate Sponge: Preparation and Application in Curcumin Delivery for Dermal Wound Healing in Rat," *J. Biomed. Biotechnol.*, vol. 2009, pp. 1–8, 2009, doi: 10.1155/2009/595126.
59. W. Zhang, J. Zhang, Q. Jiang, and W. Xia, "The hypolipidemic activity of chitosan nanopowder prepared by ultrafine milling," *Carbohydr. Polym.*, vol. 95, no. 1, pp. 487–491, Jun. 2013, doi: 10.1016/j.carbpol.2013.02.037.





Annlin Bezy et al.,

60. M. Sugano, S. Watanabe, A. Kishi, M. Izume, and A. Ohtakara, "Hypocholesterolemic action of chitosans with different viscosity in rats," *Lipids*, vol. 23, no. 3, pp. 187–191, Mar. 1988, doi: 10.1007/BF02535456.
61. S. N. Chirkov, "The Antiviral Activity of Chitosan (Review)," *Appl. Biochem. Microbiol.*, vol. 38, no. 1, pp. 1–8, 2002, doi: 10.1023/A:1013206517442.
62. A. Anitha, S. Maya, N. Deepa, K. P. Chennazhi, S. V. Nair, and R. Jayakumar, "Curcumin-Loaded N , O - Carboxymethyl Chitosan Nanoparticles for Cancer Drug Delivery," *J. Biomater. Sci. Polym. Ed.*, vol. 23, no. 11, pp. 1381–1400, Aug. 2012, doi: 10.1163/092050611X581534.
63. M. A. Mofazzal Jahromi et al., "Curcumin-loaded Chitosan Tripolyphosphate Nanoparticles as a safe, natural and effective antibiotic inhibits the infection of Staphylococcus aureus and Pseudomonas aeruginosa in vivo," *Iran. J. Biotechnol.*, vol. 12, no. 3, pp. 1–8, Sep. 2014, doi: 10.15171/ijb.1012.
64. R. Jayakumar et al., "Preparation, characterization, bioactive and metal uptake studies of alginate/phosphorylated chitin blend films," *Int. J. Biol. Macromol.*, vol. 44, no. 1, pp. 107–111, Jan. 2009, doi: 10.1016/j.ijbiomac.2008.10.010.
65. K. H. Reeta, J. Mehla, and Y. K. Gupta, "Curcumin is protective against phenytoin-induced cognitive impairment and oxidative stress in rats," *Brain Res.*, vol. 1301, pp. 52–60, Nov. 2009, doi: 10.1016/j.brainres.2009.09.027.
66. S. C. Gupta, S. Patchva, and B. B. Aggarwal, "Therapeutic Roles of Curcumin: Lessons Learned from Clinical Trials," *AAPS J.*, vol. 15, no. 1, pp. 195–218, Jan. 2013, doi: 10.1208/s12248-012-9432-8.
67. J. Shaikh, D. D. Ankola, V. Beniwal, D. Singh, and M. N. V. R. Kumar, "Nanoparticle encapsulation improves oral bioavailability of curcumin by at least 9-fold when compared to curcumin administered with piperine as absorption enhancer," *Eur. J. Pharm. Sci.*, vol. 37, no. 3–4, pp. 223–230, Jun. 2009, doi: 10.1016/j.ejps.2009.02.019.
68. V. Torchilin, "Multifunctional and stimuli-sensitive pharmaceutical nanocarriers," *Eur. J. Pharm. Biopharm.*, vol. 71, no. 3, pp. 431–444, Mar. 2009, doi: 10.1016/j.ejpb.2008.09.026.
69. P. Ruenraroengsak, J. M. Cook, and A. T. Florence, "Nanosystem drug targeting: Facing up to complex realities," *J. Control. Release*, vol. 141, no. 3, pp. 265–276, Feb. 2010, doi: 10.1016/j.jconrel.2009.10.032.
70. S. Sultana, M. R. Khan, M. Kumar, S. Kumar, and M. Ali, "Nanoparticles-mediated drug delivery approaches for cancer targeting: a review," *J. Drug Target.*, vol. 21, no. 2, pp. 107–125, Feb. 2013, doi: 10.3109/1061186X.2012.712130.
71. S. Singh and B. B. Aggarwal, "Activation of Transcription Factor NF- κ B Is Suppressed by Curcumin (Diferuloylmethane)," *J. Biol. Chem.*, vol. 270, no. 42, pp. 24995–25000, Oct. 1995, doi: 10.1074/jbc.270.42.24995.
72. Y.-J. Surh and K.-S. Chun, "CANCER CHEMOPREVENTIVE EFFECTS OF CURCUMIN," in *The Molecular Targets and Therapeutic Uses of Curcumin in Health and Disease*, Boston, MA: Springer US, 2007, pp. 149–172. doi: 10.1007/978-0-387-46401-5_5.
73. X. Liu et al., "Net-like porous activated carbon materials from shrimp shell by solution-processed carbonization and H₃PO₄ activation for methylene blue adsorption," *Powder Technol.*, vol. 326, pp. 181–189, Feb. 2018, doi: 10.1016/j.powtec.2017.12.034.
74. R. Chauhan et al., "Radiation-induced curcumin release from curcumin–chitosan polymer films," *RSC Adv.*, vol. 10, no. 27, pp. 16110–16117, 2020, doi: 10.1039/D0RA00144A.
75. H. Xu et al., "Supramolecular Nanofibers of Curcumin for Highly Amplified Radiosensitization of Colorectal Cancers to Ionizing Radiation," *Adv. Funct. Mater.*, vol. 28, no. 14, p. 1707140, Apr. 2018, doi: 10.1002/adfm.201707140.
76. S. Gordon, A. Saupé, W. McBurney, T. Rades, and S. Hook, "Comparison of chitosan nanoparticles and chitosan hydrogels for vaccine delivery," *J. Pharm. Pharmacol.*, vol. 60, no. 12, pp. 1591–1600, Dec. 2008, doi: 10.1211/jpp/60.12.0004.
77. Y. Luo and Q. Wang, "Recent development of chitosan-based polyelectrolyte complexes with natural polysaccharides for drug delivery," *Int. J. Biol. Macromol.*, vol. 64, pp. 353–367, Mar. 2014, doi: 10.1016/j.ijbiomac.2013.12.017.
78. Y. Rojanasakul, L. Wang, M. Bhat, D. D. Glover, C. J. Malanga, and J. K. H. Ma, "The Transport Barrier of Epithelia: A Comparative Study on Membrane Permeability and Charge Selectivity in the Rabbit," *Pharm. Res.*, vol. 09, no. 8, pp. 1029–1034, 1992, doi: 10.1023/A:1015802427428.





Annlin Bezy et al.,

79. M. Thanou, J. Verhoef, and H. Junginger, "Chitosan and its derivatives as intestinal absorption enhancers," *Adv. Drug Deliv. Rev.*, vol. 50, pp. S91–S101, Oct. 2001, doi: 10.1016/S0169-409X(01)00180-6.
80. M. M. K. Modasiya and V. M. Patel, "Studies on solubility of curcumin," 2012.
81. D. de M. Carvalho, K. P. Takeuchi, R. M. Geraldine, C. J. de Moura, and M. C. L. Torres, "Production, solubility and antioxidant activity of curcumin nanosuspension," *Food Sci. Technol.*, vol. 35, no. 1, pp. 115–119, Mar. 2015, doi: 10.1590/1678-457X.6515.
82. A. E. Krausz et al., "Curcumin-encapsulated nanoparticles as innovative antimicrobial and wound healing agent," *Nanomedicine Nanotechnology, Biol. Med.*, vol. 11, no. 1, pp. 195–206, Jan. 2015, doi: 10.1016/j.nano.2014.09.004.
83. K. K. Chereddy et al., "Combined effect of PLGA and curcumin on wound healing activity," *J. Control. Release*, vol. 171, no. 2, pp. 208–215, Oct. 2013, doi: 10.1016/j.jconrel.2013.07.015.
84. L. Thomas, F. Zakir, M. A. Mirza, M. K. Anwer, F. J. Ahmad, and Z. Iqbal, "Development of Curcumin loaded chitosan polymer based nanoemulsion gel: In vitro, ex vivo evaluation and in vivo wound healing studies," *Int. J. Biol. Macromol.*, vol. 101, pp. 569–579, Aug. 2017, doi: 10.1016/j.ijbiomac.2017.03.066.
85. V. Kant, A. Gopal, N. N. Pathak, P. Kumar, S. K. Tandan, and D. Kumar, "Antioxidant and anti-inflammatory potential of curcumin accelerated the cutaneous wound healing in streptozotocin-induced diabetic rats," *Int. Immunopharmacol.*, vol. 20, no. 2, pp. 322–330, Jun. 2014, doi: 10.1016/j.intimp.2014.03.009.
86. W. M. El-Refaie, Y. S. R. Elnaggar, M. A. El-Massik, and O. Y. Abdallah, "Novel curcumin-loaded gel-core hyalurosomes with promising burn-wound healing potential: Development, in-vitro appraisal and in-vivo studies," *Int. J. Pharm.*, vol. 486, no. 1–2, pp. 88–98, May 2015, doi: 10.1016/j.ijpharm.2015.03.052.
87. G. Guo et al., "EGF and curcumin co-encapsulated nanoparticle/hydrogel system as potent skin regeneration agent," *Int. J. Nanomedicine*, vol. Volume 11, pp. 3993–4009, Aug. 2016, doi: 10.2147/IJN.S104350.
88. C. Gong et al., "A biodegradable hydrogel system containing curcumin encapsulated in micelles for cutaneous wound healing," *Biomaterials*, vol. 34, no. 27, pp. 6377–6387, Sep. 2013, doi: 10.1016/j.biomaterials.2013.05.005.
89. F. Croisier and C. Jérôme, "Chitosan-based biomaterials for tissue engineering," *Eur. Polym. J.*, vol. 49, no. 4, pp. 780–792, Apr. 2013, doi: 10.1016/j.eurpolymj.2012.12.009.
90. D. SHI, F. WANG, T. LAN, Y. ZHANG, and Z. SHAO, "Convenient fabrication of carboxymethyl cellulose electrospun nanofibers functionalized with silver nanoparticles," *Cellulose*, vol. 23, no. 3, pp. 1899–1909, Jun. 2016, doi: 10.1007/s10570-016-0918-x.
91. P. Marie Arockianathan, S. Sekar, B. Kumaran, and T. P. Sastry, "Preparation, characterization and evaluation of biocomposite films containing chitosan and sago starch impregnated with silver nanoparticles," *Int. J. Biol. Macromol.*, vol. 50, no. 4, pp. 939–946, May 2012, doi: 10.1016/j.ijbiomac.2012.02.022.
92. A. Vaiserman, A. Koliada, A. Zayachkivska, and O. Lushchak, "Nanodelivery of Natural Antioxidants: An Anti-aging Perspective," *Front. Bioeng. Biotechnol.*, vol. 7, Jan. 2020, doi: 10.3389/fbioe.2019.00447.
93. C. E. Mora-Huertas, H. Fessi, and A. Elaissari, "Polymer-based nanocapsules for drug delivery," *Int. J. Pharm.*, vol. 385, no. 1–2, pp. 113–142, Jan. 2010, doi: 10.1016/j.ijpharm.2009.10.018.
94. C. Preetz, A. Rube, I. Reiche, G. Hause, and K. Mäder, "Preparation and characterization of biocompatible oil-loaded polyelectrolyte nanocapsules," *Nanomedicine Nanotechnology, Biol. Med.*, vol. 4, no. 2, pp. 106–114, Jun. 2008, doi: 10.1016/j.nano.2008.03.003.
95. Y. Baspinar, M. Üstündas, O. Bayraktar, and C. Sezgin, "Curcumin and piperine loaded zein-chitosan nanoparticles: Development and in-vitro characterisation," *Saudi Pharm. J.*, vol. 26, no. 3, pp. 323–334, Mar. 2018, doi: 10.1016/j.jsps.2018.01.010.
96. L. H. Chuah, N. Billa, C. J. Roberts, J. C. Burley, and S. Manickam, "Curcumin-containing chitosan nanoparticles as a potential mucoadhesive delivery system to the colon," *Pharm. Dev. Technol.*, vol. 18, no. 3, pp. 591–599, Jun. 2013, doi: 10.3109/10837450.2011.640688.
97. T. H. Fischer, R. Connolly, H. S. Thatte, and S. S. Schwaizberg, "Comparison of structural and hemostatic properties of the poly-N-acetyl glucosamine Syvek Patch with products containing chitosan," *Microsc. Res. Tech.*, vol. 63, no. 3, pp. 168–174, Feb. 2004, doi: 10.1002/jemt.20017.





Annlin Bezy et al.,

98. I. Helander, E.-L. Nurmiaho-Lassila, R. Ahvenainen, J. Rhoades, and S. Roller, "Chitosan disrupts the barrier properties of the outer membrane of Gram-negative bacteria," *Int. J. Food Microbiol.*, vol. 71, no. 2–3, pp. 235–244, Dec. 2001, doi: 10.1016/S0168-1605(01)00609-2.
99. L. Duse et al., "Preparation and Characterization of Curcumin Loaded Chitosan Nanoparticles for Photodynamic Therapy," *Phys. status solidi*, vol. 215, no. 15, p. 1700709, Aug. 2018, doi: 10.1002/pssa.201700709.
100. R. S. Nair, A. Morris, N. Billa, and C.-O. Leong, "An Evaluation of Curcumin-Encapsulated Chitosan Nanoparticles for Transdermal Delivery," *AAPS PharmSciTech*, vol. 20, no. 2, p. 69, Feb. 2019, doi: 10.1208/s12249-018-1279-6.
101. M. G. O'Toole et al., "Release-Modulated Antioxidant Activity of a Composite Curcumin-Chitosan Polymer," *Biomacromolecules*, vol. 17, no. 4, pp. 1253–1260, Apr. 2016, doi: 10.1021/acs.biomac.5b01019.
102. S. A. Agnihotri, N. N. Mallikarjuna, and T. M. Aminabhavi, "Recent advances on chitosan-based micro- and nanoparticles in drug delivery," *J. Control. Release*, vol. 100, no. 1, pp. 5–28, Nov. 2004, doi: 10.1016/j.jconrel.2004.08.010.
103. S. De, "Polymer relationships during preparation of chitosan–alginate and poly-l-lysine–alginate nanospheres," *J. Control. Release*, vol. 89, no. 1, pp. 101–112, Apr. 2003, doi: 10.1016/S0168-3659(03)00098-1.
104. S. Deljoo, N. Rabiee, and M. Rabiee, "Curcumin-hybrid Nanoparticles in Drug Delivery System (Review)," *Asian J. Nanosci. Mater.*, vol. 2, no. 1, pp. 66–91, 2019, doi: 10.26655/ajnanomat.2019.1.5.
105. V. Thamilarasan et al., "Single Step Fabrication of Chitosan Nanocrystals Using *Penaeus semisulcatus*: Potential as New Insecticides, Antimicrobials and Plant Growth Promoters," *J. Clust. Sci.*, vol. 29, no. 2, pp. 375–384, Mar. 2018, doi: 10.1007/s10876-018-1342-1.
106. P. Morganti and M.-B. Coltelli, "A New Carrier for Advanced Cosmeceuticals," *Cosmetics*, vol. 6, no. 1, p. 10, Feb. 2019, doi: 10.3390/cosmetics6010010.
107. H. S. Whang, W. Kirsch, Y. H. Zhu, C. Z. Yang, and S. M. Hudson, "Hemostatic Agents Derived from Chitin and Chitosan," *J. Macromol. Sci. Part C Polym. Rev.*, vol. 45, no. 4, pp. 309–323, Oct. 2005, doi: 10.1080/15321790500304122.
108. H. C. Hemker, R. Al Dieri, and S. B??guin, "Thrombin generation assays: accruing clinical relevance," *Curr. Opin. Hematol.*, vol. 11, no. 3, pp. 170–175, May 2004, doi: 10.1097/01.moh.0000130314.33410.d7.
109. P. R. Klokkevold, H. Fukayama, E. C. Sung, and C. N. Bertolami, "The effect of chitosan (poly-N-acetyl glucosamine) on lingual hemostasis in heparinized rabbits," *J. Oral Maxillofac. Surg.*, vol. 57, no. 1, pp. 49–52, Jan. 1999, doi: 10.1016/S0278-2391(99)90632-8.
110. S. B. Rao and C. P. Sharma, "Use of chitosan as a biomaterial: Studies on its safety and hemostatic potential," *J. Biomed. Mater. Res.*, vol. 34, no. 1, pp. 21–28, Jan. 1997, doi: 10.1002/(SICI)1097-4636(199701)34:1<21::AID-JBM4>3.0.CO;2-P.
111. S. ROLLER and N. COVILL, "The Antimicrobial Properties of Chitosan in Mayonnaise and Mayonnaise-Based Shrimp Salads," *J. Food Prot.*, vol. 63, no. 2, pp. 202–209, Feb. 2000, doi: 10.4315/0362-028X-63.2.202.
112. Y.-L. Chen and C.-C. Chou, "Factors affecting the susceptibility of *Staphylococcus aureus* CCRC 12657 to water soluble lactose chitosan derivative," *Food Microbiol.*, vol. 22, no. 1, pp. 29–35, Jan. 2005, doi: 10.1016/j.fm.2004.05.005.
113. B. JOE, M. VIJAYKUMAR, and B. R. LOKESH, "Biological Properties of Curcumin-Cellular and Molecular Mechanisms of Action," *Crit. Rev. Food Sci. Nutr.*, vol. 44, no. 2, pp. 97–111, Mar. 2004, doi: 10.1080/10408690490424702.
114. H. M. Basit, M. C. I. Mohd Amin, S.-F. Ng, H. Katas, S. U. Shah, and N. R. Khan, "Formulation and Evaluation of Microwave-Modified Chitosan-Curcumin Nanoparticles—A Promising Nanomaterials Platform for Skin Tissue Regeneration Applications Following Burn Wounds," *Polymers (Basel)*, vol. 12, no. 11, p. 2608, Nov. 2020, doi: 10.3390/polym12112608.
115. R. Ramya, J. Venkatesan, S. K. Kim, and P. N. Sudha, "Biomedical Applications of Chitosan: An Overview," *J. Biomater. Tissue Eng.*, vol. 2, no. 2, pp. 100–111, Jun. 2012, doi: 10.1166/jbt.2012.1030.





Annlin Bezy et al.,

116. X. Huang, Y.-Z. Du, H. Yuan, and F.-Q. Hu, "Preparation and pharmacodynamics of low-molecular-weight chitosan nanoparticles containing insulin," *Carbohydr. Polym.*, vol. 76, no. 3, pp. 368–373, Apr. 2009, doi: 10.1016/j.carbpol.2008.10.025.
117. Y. Yin et al., "Itaconic acid grafted carboxymethyl chitosan and its nanoparticles: Preparation, characterization and evaluation," *Int. J. Biol. Macromol.*, vol. 102, pp. 10–18, Sep. 2017, doi: 10.1016/j.ijbiomac.2017.04.005.
118. Y. Li et al., "Therapeutic effects of EGF-modified curcumin/chitosan nano-spray on wound healing," *Regen. Biomater.*, vol. 8, no. 2, Mar. 2021, doi: 10.1093/rb/rbab009.
119. A. D. Juncos Bombin, N. J. Dunne, and H. O. McCarthy, "Electrospinning of natural polymers for the production of nanofibres for wound healing applications," *Mater. Sci. Eng. C*, vol. 114, p. 110994, Sep. 2020, doi: 10.1016/j.msec.2020.110994.
120. M. Yanat and K. Schroën, "Preparation methods and applications of chitosan nanoparticles; with an outlook toward reinforcement of biodegradable packaging," *React. Funct. Polym.*, vol. 161, p. 104849, Apr. 2021, doi: 10.1016/j.reactfunctpolym.2021.104849.
121. J. J. Perez and N. J. Francois, "Chitosan-starch beads prepared by ionotropic gelation as potential matrices for controlled release of fertilizers," *Carbohydr. Polym.*, vol. 148, pp. 134–142, Sep. 2016, doi: 10.1016/j.carbpol.2016.04.054.
122. Y. Tan and C.-G. Liu, "Self-aggregated nanoparticles from linoleic acid modified carboxymethyl chitosan: Synthesis, characterization and application in vitro," *Colloids Surfaces B Biointerfaces*, vol. 69, no. 2, pp. 178–182, Mar. 2009, doi: 10.1016/j.colsurfb.2008.11.026.
123. K.-Y. Chen and S.-Y. Zeng, "Fabrication of Quaternized Chitosan Nanoparticles Using Tripolyphosphate/Genipin Dual Cross-Linkers as a Protein Delivery System," *Polymers (Basel)*, vol. 10, no. 11, p. 1226, Nov. 2018, doi: 10.3390/polym10111226.
124. P. Rachtanapun et al., "Characterization of Chitosan Film Incorporated with Curcumin Extract," *Polymers (Basel)*, vol. 13, no. 6, p. 963, Mar. 2021, doi: 10.3390/polym13060963.
125. F. Wang, R. Wang, Y. Pan, M. Du, Y. Zhao, and H. Liu, "Gelatin/Chitosan Films Incorporated with Curcumin Based on Photodynamic Inactivation Technology for Antibacterial Food Packaging," *Polymers (Basel)*, vol. 14, no. 8, p. 1600, Apr. 2022, doi: 10.3390/polym14081600.
126. A. Bhatnagar and M. Sillanpää, "Applications of chitin- and chitosan-derivatives for the detoxification of water and wastewater – A short review," *Adv. Colloid Interface Sci.*, vol. 152, no. 1–2, pp. 26–38, Nov. 2009, doi: 10.1016/j.cis.2009.09.003.
127. S. Moradi Dehaghi, B. Rahmanifar, A. M. Moradi, and P. A. Azar, "Removal of permethrin pesticide from water by chitosan–zinc oxide nanoparticles composite as an adsorbent," *J. Saudi Chem. Soc.*, vol. 18, no. 4, pp. 348–355, Sep. 2014, doi: 10.1016/j.jscs.2014.01.004.
128. M. S. Sivakami, T. Gomathi, J. Venkatesan, H.-S. Jeong, S.-K. Kim, and P. N. Sudha, "Preparation and characterization of nano chitosan for treatment wastewaters," *Int. J. Biol. Macromol.*, vol. 57, pp. 204–212, Jun. 2013, doi: 10.1016/j.ijbiomac.2013.03.005.
129. M. A. Khan, M. Zafaryab, S. H. Mehdi, I. Ahmad, and M. M. A. Rizvi, "Characterization and anti-proliferative activity of curcumin loaded chitosan nanoparticles in cervical cancer," *Int. J. Biol. Macromol.*, vol. 93, pp. 242–253, Dec. 2016, doi: 10.1016/j.ijbiomac.2016.08.050.





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<p style="text-align: center;">PROPERTIES</p> <div style="display: flex; justify-content: space-around;"> <div style="text-align: center;"> <p>CHITOSAN</p> <ul style="list-style-type: none"> — Cytocompatibility — Lack of toxicity — Antimicrobial Activi — Adsorption — Biodegradability </div> <div style="text-align: center;"> <p>CURCUMIN</p> <ul style="list-style-type: none"> — Anti Bacterial — Immunomodulator — Neuroprotective — Anti tumour — Cardiovascular Protection </div> </div>	
<p style="text-align: center;">Graphical Abstract</p>	<p style="text-align: center;">Figure 1 Extraction process of chitosan from shrimp shells</p>
<p style="text-align: center;">Figure 2 Extraction process of curcumin from turmeric</p>	<p style="text-align: center;">Figure 3 Applications of chitosan-curcumin matrix</p>





Hybrid Approach of Combined RNN and the SALP Optimization Technique to Detect the Intrusions using the LSSA Algorithm

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ABSTRACT

The data transmission plays a crucial role in today's digital world. The security of sending and receiving the sensitive information is still a challenging task for many people. Day by day the occurrence of data breaches and the threats are happening in the digital world. The machine learning algorithms combined with the deep learning approaches and the optimization techniques will help to overcome the problem of the loss of data. The data preprocessing process is done and the feature selection process is performed to enhance and increase the performance of the algorithm. This combined approach provides good results with an accuracy of about 96.06 percentage. The algorithm efficiency should be improved to handle all types of attacks. In this paper the hybrid approach of the combined LSTM and SALP optimization called as LSSA algorithm is used to find the intrusions.

Keywords: LSTM, SALP Swarm optimization

INTRODUCTION

The IDS is the very important security that should be implemented in every organization for the security. In this the detection can be done for the network. The network traffic is analyzed for the security purposes to check the abnormal activity. The key task in the network intrusion detection is analyzing the traffic in various aspects. The traffic is analyzed by performing the signature matching in database or finding the abnormal activity in the network.



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The main aim of the detection is to help the organization or concern to secure the data in various aspects. The IDS helps the organization to predict the threat in earlier so suitable actions can be taken to overcome the problem. The sensitive information can be predicted. If the company is maintaining the customer information, then if data breaches occurred then the reputation of the company will be lost. So, it gives the security to the sensitive information in various aspects. The intrusion detection will help to detect the malicious activity and it will generate the immediate alert to secure the data. The network health can be monitored and good networking is enhanced. It is one of the important aspects in the cyber security measures to create the good networking environment. The intrusion detection can be used to analyze the network behaviour and it is also used to identify the pattern of the network. It also helps to create the automated response and the alert options. It provides the continuous monitoring of the network. The network intrusion detection can be done by using the deep learning architectures for performing the detection. The convolutional neural network is used to perform the feature selection process. This network is very useful in analyzing the patterns, analyzing the video and the audio data etc. The neural network is very important for the machine learning and there are many different types of network architectures. The neural network contains the weights and the threshold and it will be activated when the threshold value is above the minimum value. It contains different layers like input layer, hidden layer and the output layers. The convolutional neural network is very supportive for the image recognition for the large data sets. There are three layers in the convolutional neural network. They are convolutional layers, pooling layers, and the fully connected layer. These layers will be very much helpful in identifying the patterns and the initial process is finding the color and the edge and later on the layers will be very helpful in identifying the complex patterns of the object. There are some problems in the intrusion detection that is suffering from the false positives. The false positives should be reduced that is not that much efficient in older methods. The false positives are nothing but the normal packets are detected as the malicious packets.

LITERATURE SURVEY

The author LirimAshikuet al [1] states that the interconnection between the systems is much important for the digital communication. During communication there are many vulnerabilities which will compromise the system to access our secured information. The author has used the deep learning techniques which will alert the system to secure the information. It will help to classify the attacks and the normal data which will help in reducing the risk of occurring the threats. The DNN will help to detect all the attacks that happens in the network. The author has used the UNSW-NB15 data set for model development. The model has provided some results which was between 95.4% to 95.6%. They suggested to use the model to detect the zero-day attacks. So, it will reduce the risk of compromising the systems. Wang Peng et al [2] stated that the network is very difficult to manage without threats. Day by day new type of threats are arising in the network. The author uses the deep confidence neural network and the back propagation NN for detecting the intrusions. The data set used in this experiment is KDD Cup 99 data set. Three different kinds of feature selection methods are used to detect the malicious packet. The author suggested that the model has given the good promising results when it is compared to the traditional methods. Sara AI Emadi et al [3] has stated that the intrusion has been increased nowadays and various cyber-crimes are occurring nowadays. The problem can be solved by using the CNN along with recurrent neural network which will help to develop the efficient detection system. Further the model is compared with other methods to highlight the performance.

The author has used the NSL KDD data set which is an updated version of the KDD cup data set. The CNN outperforms well and the accuracy is about 97% and the main disadvantage is it takes more time to train the model. The future model which is going to be developed should be focused on these areas. Mohammed Maithem et al [4] states that the IDS is very much important for the networking system. The detection is done in two ways. One is multiclass and other is binary class. There are 22 different kinds of attacks. The author has used the KDD cup 99 data set for model development. The maximum level of accuracy is detected in this model. Amjad Rehman Khan et al [5] tells that the generation of data in IOT is more in number and the risk occurring threats is also increased. The efficient system is necessary for securing the information. The data is generated in usage of smart homes, smart cities and other IOT enabled sectors. The efficiency of the model is evaluated by using the performance metrics. The required



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security should be initiated for IOT devices. Alaa Mohammed Banaamah et al[6] proposed the CNN along with the LSTM method to predict the attacks. The author has used the BOT data sets and the generated results have been compared with the previous methods. The author suggested to use other classifiers like genetic algorithm and BiLSTM can be used to achieve the results. Abiodun Ayantayo et al [7] states that intrusion detection is done with the help of the deep learning techniques which will be very much helpful for detecting the attacks at the earlier stage. They have been using the feature fusion methods which will help to improve the accuracy. The late fusion method has shown the best results. The author has used UNSW-NB15 dataset. Zeeshan Ahmad et al [8] states that there was a huge increase in the network size and the day-to-day occurrence of the intrusion is more in number. To overcome this problem the ML and the DL learning methods can be used to detect the intrusions. Based on the ML and DL techniques various reviews have been analyzed and valuable suggestions have been given for further implementation. MD AI-Imran et al [9] proposed that many companies are installing the cyber security protection to secure their companies data for the long time. The author has conducted some experiments by using the existing methods SVM, Decision tree, and KNN. In the second phase random forest and the XG boost methods are used to see the results. Finally, the methods like feed forward, LSTM, Gated Recurrent Unit neural network are combined together to get the results.

Problem statement

The network intrusion detection becomes the very challenging and the difficult environment for many concerns. They require highly trusted and the very much efficient system for the threat detection. This can be done with the help of the hybrid deep learning model that is convolutional neural network and the LSTM which is special recurrent neural network along with SALP optimization technique which will be very much helpful for the detecting the intrusions.

METHODOLOGY**Convolutional Neural Network**

The convolutional neural network is used to understand the visual data. The spatial dependencies in the network like routers, access points and the devices play the important role in network performance. The attributes like signal strength, interference, latency is affected by the spatial dependencies. So, the convolutional neural network is very much effective in capturing this spatial information and it is very important for analyzing the network intrusion. This model is very much helpful for analyzing the complex structures in the network. It is also very much helpful for handling the large amount of data. The convolutional layers contain multiple layers which was used to extract the features. It contains various layers they are input layer, convolutional layer, max pooling layer, dense layer, output layer. The convolutional layers apply various filters to extract features to the input images. The pooling layer performs the down sampling technique to reduce the computation of the image. The fully connected layer finally performs the final prediction. In convolutional neural network small patch is taken from the input image and the height and the width will be same. Then the small patch is undergone a small neural network. Then slide it vertically and the new image with different height and the width is generated. In convolutional layers the n number of filters are generated and there by feature map is created. Hence the generation of filters is more in number and then the activation layer is used to take only the maximum values in an image. The pooling layer is mainly to reduce the size of the image.

Layers in Convolutional neural Network

There are many layers in the convolutional neural network. They are as follows,

- Input layer
- Convolutional layers
 - Relu layers
 - Pooling layer





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- Fully connected layer

The artificial neural network is the basis for the convolutional neural network but there are some limitations in the ANN that is the neural network cannot deal with very complex images. The CNN will be very much helpful in dealing with very complex images.

Input layer

The input layer is the one which that helps to receive the input.

Convolutional layer

The convolutional layer is the next layer in the CNN which contains many filters which will be used to recognize the images. There are different types of filters. After filtering the image is represented in the form of the matrix format. It can be 3*3 or 4*4 or 5*5. The values in the matrix are finally averaged. This average is called feature map. All these individual feature maps are combined together to form the full image. This can be done by the fully connected layer. The CNN performs both the classification and the feature extraction. The convolutional layer contains the other two layers is that is Relu and the pooling layers.

Relu layer

The Relu layer is used to replace the negative values into null in the feature map. It will make the model into nonlinear. It will help to reduce the dimension. It will also help to reduce the overfitting of the data. It is tolerant to any variations.

Pooling layer

The pooling layer is used to reduce the size of the image. There are two types of pooling. The first type of pooling is max pooling and the other one is average pooling. The max pooling will pick the maximum value in the feature map and the average pooling will average the values in the feature map.

LSTM

The long short-term memory is the one of the recurrent neural networks which will be very much useful to retain the data for the long term. This can do the predictions and classify the data for the long term. This can handle the sequential data very effectively. It also overcomes the problem in the recurrent neural network which will work for the short term or current data prediction. The LSTM contains the memory cell which is very useful to overcome this problem. It is controlled by three gates that is input gate, forget gate and the output gate. The information which should be present and which not be there is decided by the memory cell. The LSTM can handle the sequential data very easily. It is useful for many applications like speech recognition and the natural language processing. It can handle long term dependencies very easily. The traditional methods are lacking in handling the long-term dependencies. The three cells help to retain the needed information for the network. This LSTM is combined with other neural network to identify the complex patterns. In this work the LSTM is combined with the CNN so it will be very much helpful for identifying the patterns in the network. The LSTM contains the four neural networks and the cell.

Forget gate

The items which were not needed for the long time is discarded in this gate. There are two inputs that will be passed to the gate and it will be multiplied with the weight and the resultant output is passed to the activation function. The data status that will be forgotten or retained will be based on the output value. If the value is 0 then the data will be forgotten and if the value is 1 then the value will be retained.

$$f_t = \sigma(W_f \cdot [h_{t-1}, x_t] + b_f)$$





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The above is the formula for the forget gate. It will make the future adjustments to update the information in the memory.

Input Gate

The input gate is very much useful for addition of information in the memory. The formulas used in the input gate are defined below.

$$i_t = \sigma(W_i \cdot [h_{t-1}, x_t] + b_i)$$

$$\hat{C}_t = \tanh(W_c \cdot [h_{t-1}, x_t] + b_c)$$

$$C_t = f_t \odot C_{t-1} + i_t \odot \hat{C}_t$$

Output Gate

The output gate is used to get the useful information from the current cell which will undergo various functions. Then the useful information is extracted.

$$o_t = \sigma(W_o \cdot [h_{t-1}, x_t] + b_o)$$

This LSTM will help to maintain the information for the long time. It can be applied in various areas.

Swarm optimization

There are some limitations in the CNN network in which it can be overcome by the optimization techniques. The optimization helps to find the maximum values for the parameter which will be very much useful in solving the problem. There are various metaheuristic algorithms which will be very much helpful in solving the complex problems. The algorithm is developed based on the behaviour of the flock of birds, schooling of fish etc. There are group of particles in which each one learns from its behaviour. The velocity, position and the fitness function are important in the swarm optimization. It is developed from the social behaviour of the swarm. It is developed from using the two methodologies. They are artificial life and the evolutionary computation. It can be easily implemented because there is no need of maintaining the data in memory. The optimum solution is found by identifying the best solution from the neighbour. The main features of the PSO is the best fitness of each particle, best fitness of swarm and the updating of velocity and the position of each particle. The local best and the global best solutions are found. The swarm optimization is one of the bio-inspired algorithm which will help to get the optimum solution. Instead of using the experience of single bird the solution can be combined and there is the chance of getting best solution. The particle swarm optimization is used in the NIDS for the purpose of the dimensionality reduction. This will be suitable for all networks and based on the real time situations the attacks signatures can also be updated automatically. The social group algorithm will help to solve the complex problem. There are many particles in the search space and each one can share their knowledge and experiences with each other. By combining with particle swarm optimization, it can provide the efficient and optimum solution.

Model Evaluation

This model is developed by using the combination of convolutional neural network with LSTM and SSO for network intrusion. In this method this approach is carried out to optimize the solution. The hyper-parameter tuning is done to increase the performance of the model. The hyper parameter tuning is done before training the model as it will affect the performance of the model directly. The important parameters like number of layers, LSTM units, learning rates and the dropout rates are the most important parameters which will help to improve the performance of the model. The SSO will help the network to choose the hyper-parameters and it will fit to any type of real-world network data. The best filters can be chosen for model development. Initially the feature selection process can be done. This approach will help to create the best accuracy and adaptability for the model. The step-by-step process for the model evaluation is as follows. The work of the network intrusion detection is to detect the anomalies for securing the system and alert the user to secure the confidential information. Initially the data is preprocessed and the hyper



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parameter values are set to increase the model performance. The model is very much suited for the real time network data. It can adapt itself by performing the hyper parameter tuning.

Robust Scalar method

The robust scalar removes the scale features which are very strong for the outliers. These robust scalar techniques will help to maintain the scale of the data and to reduce the outliers.

Principal Component Analysis

The principal component analysis is very much helpful for the data set which contains the high dimensions. The PCA will help to reduce the dimensions. The time and the accuracy can be achieved and it converts the correlated values to uncorrelated values. It will maintain the original important features and it will reduce the features which was not required that much. The results of the PCA is as follows.

The above diagram shows the dimensionality reduction using the PCA.

RESULTS AND DISCUSSIONS

The below chart shows the dimensionality reduction of variables using the PCA is depicted below. After performing this task, the data set is divided into training and test sets for regression task.

Model Architecture

It is sequential and it contains the various layers where the data flows from input to output. There are two types of layers are present in the model. They are dense layers and the dropout layers. The drop out layer will help to reduce the overfitting. The model consists of many dense layers with many neurons (64, 128,512,128,1). The total number of parameters which are going to be trained is 148,033. The dense layer will help to perform the feature extraction process and the drop out layer will help to reduce the overfitting process. The following layers will help to classify the data set into normal or anomaly. The model will work in a sequential way. The LSTM layers will capture the temporal dependencies of the network. There are many LSTM layers and it contains the 64 units. The drop out layer will help to prevent the overfitting of the data. The dense layer will help to generate the binary results that is normal or intrusion. The convolutional layers are used to predict the spatial features of the network. The max pooling layers will help to reduce the dimensions. The additional configurations like loss functions and the training parameters are included to effectively perform well. The training epochs are carried out for ten iterations. The model works well for the initial and even though extra care should be taken to examine the class balance, false positive and false negative. The optimization technique will help to increase the efficiency of the model. The confusion matrix is used to evaluate the model performance. The model has given good results.

CONCLUSION

The model works well for predicting the network intrusion. This can be implemented in real and there we can perform the hyper parameter tuning processing to see the results. This SALP optimization also makes the model to work well and efficient. Additional testing is done for checking the results in real world data where there will be class imbalance.

REFERENCES

1. Sara Al-Emadi, Aisha Al-Mohannadi, Felwa Al-Senaid, "Using Deep Learning Techniques for NetworkIntrusion Detection ", IEEE Access, 2020, 171-176.
2. Wang Peng, Xiangwei Kong, Guojin Peng, Xiaoya Li, Zhongjie Wang, "Network Intrusion Based on Deep Learning", IEEE Access, 2019, 431-435.





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3. Sara AI Emadi, Aisha Al-Mohannadi ,Felwa AI -Senaid, “ Using Deep Learning Techniques for Network Intrusion Detection, IEEE, 2020, 171-176.
4. Mohammed Maithem, Dr. Ghadaa A, AI – Sultany, “Network Intrusion Detection system using Deep neural Networks”, Journal of Physics :Coference series, IOP Publishing, 2021, 1-12.
5. Amjad Rehman Khan, Muhammad Kashif, Rutvij H Jhaveri, Roshani Raut, Tanzila Saba and Saeed Ali Bahaj, “ Deep Learning for Intrusion Detection and Security of Internet of things(IOT) : Current Analysis , Challenges and Possible Solutions “, Hindawi,2022, 1-13.
6. A Vinitha Dr. B. RosilineJeetha , “ Comparative Analysis for Detecting Malicious Packets in LAN Network using Bagging and Boosting Techniques “, Journal of Propulsion Technology, Vol 44 No 3 2023, 2448 – 2454.
7. A Vinitha Dr. B. RosilineJeetha,“ Detecting Intrusions using ML Algorithms : A Review”, Samdarshi, 2091-2096.
8. A Vinitha Dr. V Jaiganesh, “ Intrusion Detection System Using Machine Learning Algorithms : A Review”, Advanced Engineering Science, 2022, 2096-3246.

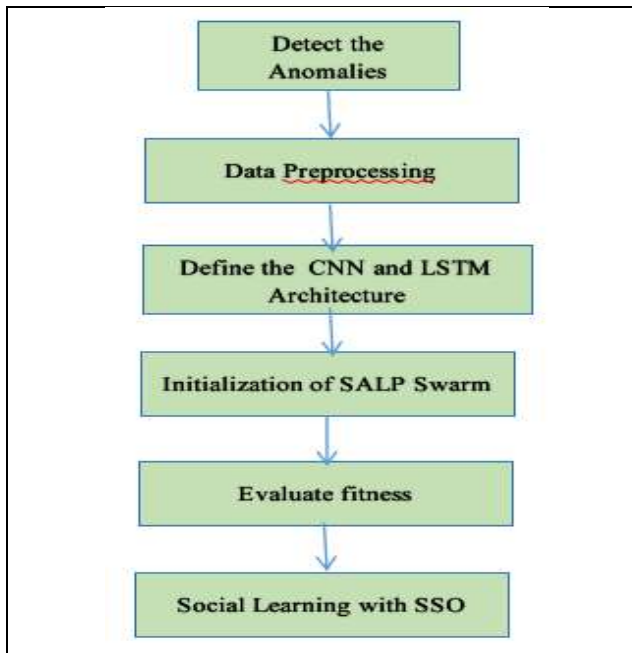


Fig 1 : Methodology

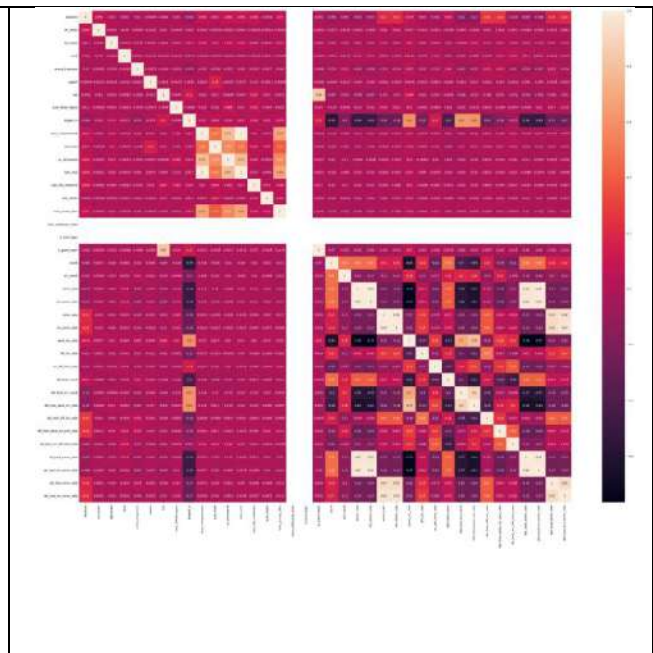


Fig 2: Dimensionality Reduction Using PCA





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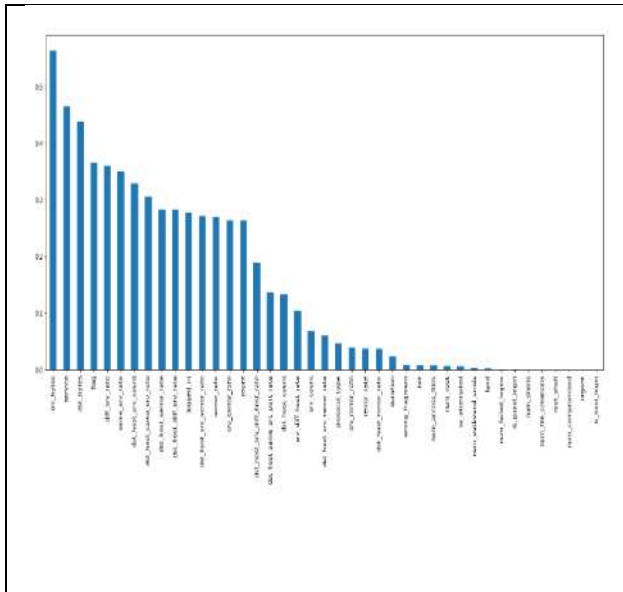


Fig 3 :Bar chart for Dimensionality Reduction

```

Epoch 1/10
363/363 [-----] - 15s 33ms/step - loss: 0.4883 - accuracy:
0.8412 - val_loss: 0.2543 - val_accuracy: 0.8930
Epoch 2/10
363/363 [-----] - 12s 33ms/step - loss: 0.2361 - accuracy:
0.9064 - val_loss: 0.1553 - val_accuracy: 0.9226
Epoch 3/10
363/363 [-----] - 11s 32ms/step - loss: 0.1766 - accuracy:
0.9276 - val_loss: 0.1256 - val_accuracy: 0.9480
Epoch 4/10
363/363 [-----] - 11s 30ms/step - loss: 0.1436 - accuracy:
0.9434 - val_loss: 0.1128 - val_accuracy: 0.9592
Epoch 5/10
363/363 [-----] - 12s 34ms/step - loss: 0.1531 - accuracy:
0.9433 - val_loss: 0.1529 - val_accuracy: 0.9318
Epoch 6/10
363/363 [-----] - 11s 30ms/step - loss: 0.1485 - accuracy:
0.9472 - val_loss: 0.1181 - val_accuracy: 0.9566
Epoch 7/10
363/363 [-----] - 11s 30ms/step - loss: 0.1294 - accuracy:
0.9545 - val_loss: 0.1064 - val_accuracy: 0.9631
Epoch 8/10
363/363 [-----] - 12s 34ms/step - loss: 0.1164 - accuracy:
0.9573 - val_loss: 0.0970 - val_accuracy: 0.9641
Epoch 9/10
363/363 [-----] - 11s 30ms/step - loss: 0.1074 - accuracy:
0.9608 - val_loss: 0.0882 - val_accuracy: 0.9661
Epoch 10/10
363/363 [-----] - 11s 31ms/step - loss: 0.1070 - accuracy:
0.9606 - val_loss: 0.0972 - val_accuracy: 0.9542
    
```

Fig 4

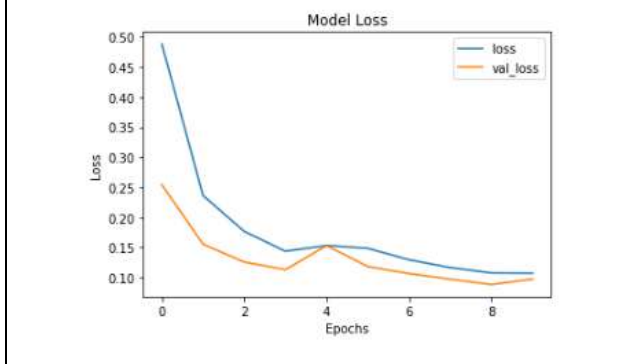


Fig 4 : Model loss

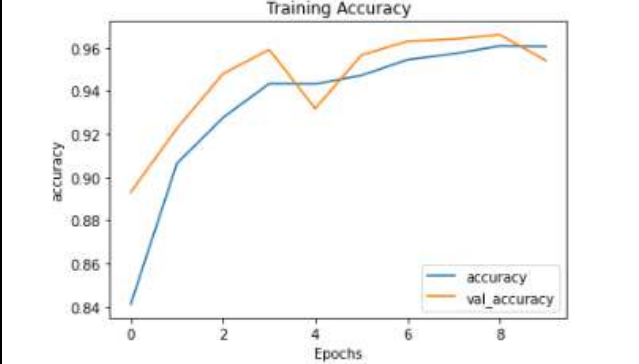


Fig 5 : Training Accuracy

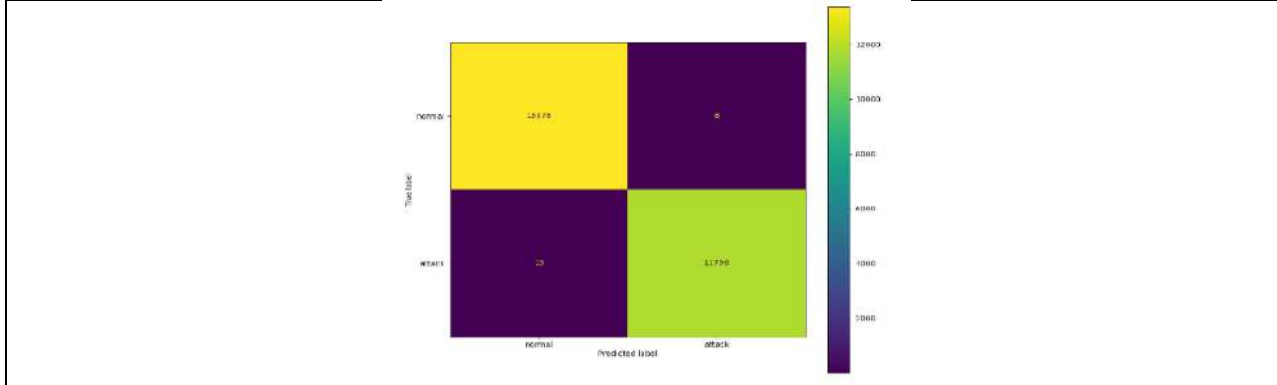


Fig 6 : Confusion Matrix





Developed a Hybrid Fast Correlation-based Feature Selection with Improved Weighed Particle Swarm Optimization to Predict and Classify Heart Disease at An Early Stage

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ABSTRACT

One of the applications of ML is the forecasting of heart disease. Optimization methods have the benefit of being able to cope with complicated non-linear issues while remaining flexible and adaptable. In this study, we used the Fast Correlation-Based Feature Selection (FCBFS) approach to remove duplicate characteristics from heart disease classification. Then, an analysis using various classification algorithms especially Support Vector Machine (SVM), K-Nearest Neighbor (KNN), Random Forest (RF), Multiplayer Perception (MLP), Naive Bayes (NB), and Artificial Neural Network (ANN) optimized using Improved Weighed Particle Swarm Optimization (IWPSO). The proposed combined technique is used in a heart condition database; the findings show that the proposed combination of methods is effective and durable in handling different kinds of information for heart disease identification. As an outcome, this research evaluates various ML algorithms and analyses the outcomes using various metrics such as Accuracy, Precision, Recall, F1-score, and Sensitivity. Using the optimized approach proposed by IWPSO





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and FCBFS achieved an optimal accuracy in classification of 99.65%. The outcomes reveal that the proposed system outperforms the previously existing classification method.

Keywords: Heart disease, Artificial Neural Network, K Nearest Neighbor, Support Vector Machine, Naïve Bayes, Random Forest, Classification, Feature selection, Ant Colony Optimization, Particle Swarm Optimization, Machine Learning

INTRODUCTION

In today's environment, Cardio Vascular Disease (CVD) is on the rise. The World Health Organization (WHO) estimates that 17 million people die every year as a result of cardiovascular illness, primarily strokes and heart attacks [1]. When an individual's condition is serious meaning that he or she needs to start taking medicines right away, this analysis might be lengthy and time-consuming, and so it's crucial to prioritize it [2]. CVD is caused by a variety of unhealthy practices. As a result, it is also vital to understand which behaviors regarding health lead to CVD. With the increasing quantity of information, ML has become a developing field. ML enables the acquisition of information from huge amounts of information that would be difficult and occasionally unattainable for humans [3]. The goal of this research is to prioritize tests for diagnosis and look at some of the risk factors for CVD. As part of this paper, 70% of the information is monitored or trained and 30% is tested using a method based on ML called classification. Smart optimization techniques are widely employed in numerous study disciplines [4, 5]. It is built by exposing specific events in nature. In basic nature and versatility, the PSO method has been effectively used for heart disease [6]. Furthermore, the ACO method was initially developed for combinatory optimization. Algorithms for ACO were recently created to handle continuous optimization challenges [7]. When tackling complicated issues, using a single optimization approach has the drawbacks of inadequate precision and generalization. The FCBFS technique [8] is employed in this paper to eliminate unnecessary and unimportant characteristics, the PSO optimization outcomes are used as the initial values of the ACO, and then a classification framework for heart disease is created after the variables are modified.

Problem statement

The FCBFS technique was used as the initial phase (pre-treatment) in this study. The optimum collection of features chosen by the feature selection techniques increases the precision of classification. The primary goal of this paper is to anticipate heart disease using various classification algorithms. Weak information-mining technology is employed to analyze heart disease information. This paper's primary achievements are as follows: Extract of categorized reliability helpful in predicting heart disease Using the FCBFS approach, eliminate duplicate and unimportant characteristics. Optimization of IWPSO methods is then considered. On the heart disease information set, multiple methods of data mining are compared. Identifying the best performance-based method for predicting heart disease. The rest of the article is structured as follows. Section 2 discusses current research in this field. Section 3 provides a full explanation of the proposed method. Section 4 describes testing that was performed with the proposed ML systems. Section 5 concludes with findings and additional study objectives.

RELATED WORK

Multiple analyses of health information sets are carried out, employing multiple classifiers and choosing feature strategies. The classification of the heart disease database has received little attention. Many of them demonstrate high classification reliability [9]. [10] Proposed a combination technique that successfully combines two AI computations, SVM and Genetic Algorithm (GA) with the wrapping method. This technique's outputs are analyzed using the LIBSVM and the WEKA information mining tools. Proposed an evaluation and follow-up mechanism. The proposed method recognizes and tracks coronary artery disease. Used automated methods of learning to diagnose cardiac problems in patients with diabetes. The Chennai Research Institute's gathering of information on 500 patients





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is utilized. There are 142 persons with the disease and 358 patients who do not. The NB method has 74% efficiency. SVM has the greatest efficiency (94.60%). Proposed that information analysis technologies be used to diagnose heart disease. The NB method was used to identify coronary artery disease. In the case of NB theorem is applied. As a result, NB has a strong principle of autonomy. The information that was used came from one of Chennai's major diabetic studies. Conducted an analysis that used a hybrid classification approach depending on the ReliefF and Rough Set (RFRS) technique to aid in the detection of coronary artery disease.

PROPOSED METHODOLOGY

Figure 1 depicts the main architecture of the proposed system. Dataset of heart disease from UCI repository is given to preprocessing (Handling of missing values, elimination and feature selection, Normalization and Resample) the data. Heart disease dataset is trained using binary classification and Feature Selection is the method of reducing the input variable to our model by using only relevant data. The preprocessed data is trained using machine learning algorithms and tested with 10 iterations. The Proposed Hybrid algorithm is the process where we train the model iteratively that results in a maximum and minimum function evaluation. After 10th iteration, the result is cross validated and predicted the disease. Characteristics are chosen from the initial data set, then the most effective selection of characteristics is optimized using hybrid method. The other side the trained dataset should be tested, preprocessed using normalization and classified. Finally the result produced based on performance measures. The attributes of the heart disease datasets of the patients depicted in Table 1.

Preprocessing

Preprocessing is a technique for obtaining full, constant, and readable data. The accuracy of information influences the mining results achieved by ML systems. Insignificant variables can degrade model performance and diminish the learning rate. As a consequence, choosing characteristics is important in preprocessing since it selects the characteristics which contribute the most to forecasting the intended output. Furthermore, because the mean maintains a characteristic's extremes, values that are missing in the FHS database are substituted by an attribute's mean, as illustrated in Equation (1).

$$\text{Attribute Mean} = \frac{\sum_{x=0}^l (\text{attribute value})x}{l} \quad \dots\dots (1)$$

Where l is the total amount of attributes with values

The data set's goal class forecasts the possibility of Coronary Heart Disease (CHD). The probability of a person who is more likely to suffer from CHD is 15.2% (644 out of 4240 entries), whereas the probability of a person who does not suffer from CHD is 84.8% (3596 out of 4240 entries). Figure 3 displays an illustration of the steps in sequence used in the study that was proposed.

Dataset and attributes

The information was gathered from the UCI ML library. The Heart Disease data set is the name of the data set, which can be obtained from the repository for ML at UCI. The UCI ML collection offers an extensive and varied collection of datasets from several disciplines. The repository has been used for a variety of academic papers and research projects.

Classification Task

Heart disease detection can be viewed as a classification or clustering challenge in the context of AI. On the other together, we created a framework based on a large set of both present and absent files information, allowing us to reduce the issue to classification.

Feature selection

This expression information contains a significant number of useless and redundant features; the process of classifying heart disease becomes increasingly difficult.





Improved Weighed Particle Swarm Optimization

The algorithm's idea is to shift these small particles until they find the optimal position. Every one of those particles possesses shown in Figure 2:

Step 1: From a place in the defining set, i.e. the coordinate's particle's speed at which it can move.

Step 2: As a result, every particle's location varies during the repetitions based on weight. It evolves based on its best neighbor, greatest position, and prior location.

Step 3: This evolution is what allows us to discover the best component.

Step 4: A neighborhood or a group of atoms that interact with the particle right away, particularly the one with the most favorable criterion. At any one time, every single particle understands:

Step 5: The value is given to the objective function because every iteration necessitates an assessment between the present particle's amount of the criteria and the value that is optimal.

The findings are displayed in Table 2 with optimization. The effect of simulation inaccuracy is additionally taken into account in this work to enhance the evaluation of the performance of classifiers. To accomplish so, we assess our classifier's efficiency in terms of Kappa as a randomly adjusted indicator of the agreement among categories in addition to real courses, Absolute mistake is defined as how guesses or forecasts resemble potential results. Root Relative Absolute Error, Root Relative Squared Error, Root Mean Squared Error, and Relative Absolute Error are all examples of errors. Table 3 displayed the analysis of classifier performance measures based on hybrid FCBH with IWPSO

Experiments and results

The next part goes over the data sets, tests, and assessment systems for heart illnesses. The Waikato Environment for Knowledge Evaluation (Weka) is used in this analysis.

Classification results

The overall goal of the experiment was to see which algorithm best classified heart disease using the provided optimization approaches. Figure 3 and 4 To avoid unstable operation outcomes, every test was conducted ten times, and the best classification accuracy was chosen for comparison.

1. Classifiers that are not optimized
2. FCBFS-optimized classifiers
3. FCBF with IWPSO-optimized classifiers

The findings are displayed in Figure 3 with optimization. The effect of simulation inaccuracy is additionally taken into account in this work to enhance the evaluation of the performance of classifiers. To accomplish so, we assess our classifier's efficiency in terms of Kappa as a randomly adjusted indicator of the agreement among categories in addition to real courses, Absolute mistake is defined as how guesses or forecasts resemble potential results. Root Relative Absolute Error, Root Relative Squared Error, Root Mean Squared Error, and Relative Absolute Error are all examples of errors. Figure 4 displayed the analysis of classifier performance measures based on hybrid FCBH with IWPSO Table 4 shows the comparison of performance measures (TP Rate, FP Rate, Precision, Recall, F-Measure) based on 3 classes i) without optimization ii) with FCBFS optimization and iii) with our proposed system for five machine learning algorithms. And it proves that our proposed FCBFS-IWPSO system produces higher accuracy than other two methods.

CONCLUSION AND FUTURE WORK

This research aimed to use AI to compare methods using various performance metrics. For test forecasting, all data were pre-processed. In certain situations, every algorithm performed better than the others. Thus, when contrasted to other current techniques, the evaluation section amply illustrated the efficacy of hybrid FCBFS-IWPSO approaches to identifying diseases. With KNN and RF the proposed optimized model by FCBFS-IWPSO achieves a precision score of 99.65%. This research can serve as a starting point for learning how to diagnose heart disease via autonomous learning, and it can be expanded upon for future studies. The research being conducted has several





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constraints, including the knowledge base of the writer, the tools employed, such as the computer's processing capacity, and the time allotted for the research. Modern tools and subject-matter expertise are needed for this kind of research. Various algorithms fared better in each of the columns previously, based on whether calibration, feature, cross-validation, and grid search selection were utilized or not.

REFERENCES

1. Malakouti, S. M. (2023). Heart disease classification based on ECG using machine learning models. *Biomedical Signal Processing and Control*, 84, 104796.
2. Chandrasekhar, N., & Peddakrishna, S. (2023). Enhancing Heart Disease Prediction Accuracy through Machine Learning Techniques and Optimization. *Processes*, 11(4), 1210.
3. Ahamad, G. N., Shafiullah, Fatima, H., Imdadullah, Zakariya, S. M., Abbas, M., ... & Usman, M. (2023). Influence of Optimal Hyperparameters on the Performance of Machine Learning Algorithms for Predicting Heart Disease. *Processes*, 11(3), 734.
4. Stojanov, D., Lazarova, E., Veljkova, E., Rubartelli, P., & Giacomini, M. (2023). Predicting the outcome of heart failure against chronic-ischemic heart disease in the elderly population–Machine learning approach based on logistic regression, case to Villa Scassi hospital Genoa, Italy. *Journal of King Saud University-Science*, 35(3), 102573.
5. Arumugam, K., Naved, M., Shinde, P. P., Leiva-Chauca, O., Huaman-Osorio, A., & Gonzales-Yanac, T. (2023). Multiple disease prediction using Machine learning algorithms. *Materials Today: Proceedings*, 80, 3682-3685.
6. Kadhim, M. A., & Radhi, A. M. (2023). Heart disease classification using optimized Machine learning algorithms. *Iraqi Journal For Computer Science and Mathematics*, 4(2), 31-42.
7. Bhatt, C. M., Patel, P., Ghetia, T., & Mazzeo, P. L. (2023). Effective heart disease prediction using machine learning techniques. *Algorithms*, 16(2), 88.
8. Li, X., Zhao, Y., Zhang, D., Kuang, L., Huang, H., Chen, W., ... & Hu, D. (2023). Development of an interpretable machine learning model associated with heavy metals' exposure to identify coronary heart disease among US adults via SHAP: Findings of the US NHANES from 2003 to 2018. *Chemosphere*, 311, 137039.
9. Maheshwari, D., Ullah, U., Marulanda, P. A. O., Jurado, A. G. O., Gonzalez, I. D., Merodio, J. M. O., & Garcia-Zapirain, B. (2023). Quantum Machine Learning Applied to Electronic Healthcare Records for Ischemic Heart Disease Classification. *Hum.-Cent. Comput. Inf. Sci*, 13(06).
10. Al-Ssulami, A. M., Alsorori, R. S., Azmi, A. M., & Aboalsamh, H. (2023). Improving Coronary Heart Disease Prediction Through Machine Learning and an Innovative Data Augmentation Technique. *Cognitive Computation*, 1-16.





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Table 1: Attributes of the Heart disease dataset

Attribute	Information Attribute	Description
Age	Integer	Age in years(29 to 77)
Sex	Integer	Gender instance (0=Female,1 =Male)
Chest Pain Type	Integer	Chest pain type(1:typicalangina,2:atypicalangina,3: non-anginalpain,4:asymptomatic)
Rest Blood Pressure	Integer	Resting blood pressure in mmHg[94,200]
Serum Cholesterol	Integer	Serum cholesterol in mg/dl[126,564]
Fasting Blood Sugar	Integer	Fasting blood sugar >120 mg/dl(0=False,1=True)
Res Electrocardiographic	Integer	Resting ECG results (0:normal,1:ST-Twave abnormality,2:LVhypertrophy)
Max Heart Rate	Integer	Maximum heart rate achieved [71,202]
Exercise Induced	Integer	Exercise-induced angina(0:No,1:Yes)
Old peak	Real	ST depression induced by exercise relative to rest[0.0, 62.0]
Slope	Integer	The slope of the peak exercise ST segment (1: up-sloping, 2:flat,3:down-sloping)
Major Vessels	Integer	Number of major vessels colored by fluoroscopy(values 0-3)
Thal	Integer	Defect types: value 3: normal, 6: fixed defect, 7: irreversible defect
Class	Integer	Diagnosis of heart disease (1: Unhealthy, 2: Healthy)

Table 2. Classifiers Performance optimized by FCFB

Evaluation criteria	K-NN	SV M	RF	NB	ML P
Time to build a model (s)	0.02	0.07	0.04	0.03	0.5
Correctly classified instances	272	227	270	234	247
Incorrectly classified instance	2	45	2	39	25

Table 3. Classifiers Performance optimized by FCFB with IWPSO

Evaluation criteria	K-NN	SV M	RF	NB	ML P
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Time to build a model (s)	0.02	0.10	0.56	0.03	0.59
Correctly classified instances	214	226	219	226	226
Incorrectly classified instance	59	46	55	45	45

Table 4: Accuracy measured by class

		TPRate	FPRate	Precision	Recall	F-Measure	Class
Classifiers without optimization	K-NN	0.853	0.358	0.885	0.853	0.869	Absence
		0.842	0.347	0.806	0.842	0.824	Presence
	SVM	0.967	0.3	0.944	0.967	0.955	Absence
		0.9	0.233	0.928	0.9	0.914	Presence
	RF	0.947	0.325	0.925	0.947	0.936	Absence
		0.875	0.253	0.902	0.875	0.888	Presence
	NB	0.967	0.3	0.944	0.967	0.955	Absence
		0.9	0.233	0.928	0.9	0.914	Presence
Classifiers optimized by FCBFS	MLP	0.933	0.292	0.945	0.933	0.939	Absence
		0.908	0.267	0.895	0.908	0.902	Presence
	K-NN	0.933	0.375	0.891	0.933	0.912	Absence
		0.825	0.267	0.877	0.825	0.85	Presence
	SVM	0.96	0.3	0.943	0.96	0.951	Absence
		0.9	0.24	0.921	0.9	0.91	Presence
	RF	0.947	0.35	0.909	0.947	0.927	Absence
		0.85	0.253	0.896	0.85	0.873	Presence
Classifiers optimized by FCBFS-IWPSO	NB	0.973	0.3	0.945	0.973	0.959	Absence
		0.9	0.227	0.935	0.9	0.917	Presence
	MLP	0.987	0.317	0.936	0.987	0.961	Absence
		0.883	0.213	0.947	0.883	0.914	Presence
	K-NN	1	0.018	0.996	1	0.999	Absence
		0.998	0	1	0.995	0.995	Presence
	SVM	0.96	0.292	0.949	0.96	0.954	Absence
		0.808	0.14	0.822	0.808	0.815	Presence
Classifiers optimized by FCBFS-IWPSO	RF	0.993	0	1	0.993	0.997	Absence
		1	0.007	0.992	1	0.996	Presence
	NB	0.907	0.2	0.85	0.907	0.877	Absence
		0.8	0.093	0.873	0.8	0.835	Presence
	MLP	0.96	0.15	0.889	0.96	0.923	Absence
		0.85	0.04	0.944	0.85	0.895	Presence





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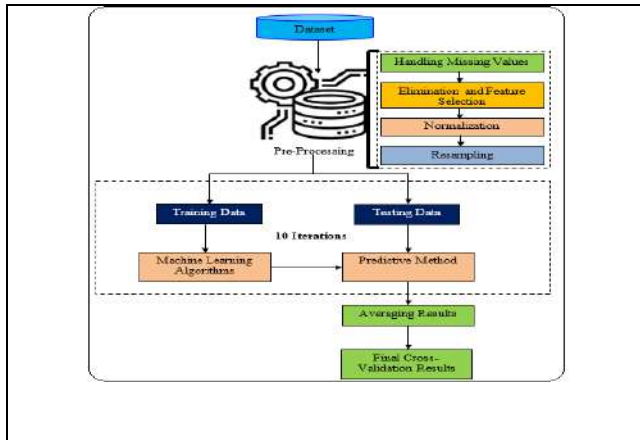


Figure 1: Steps of the proposed system

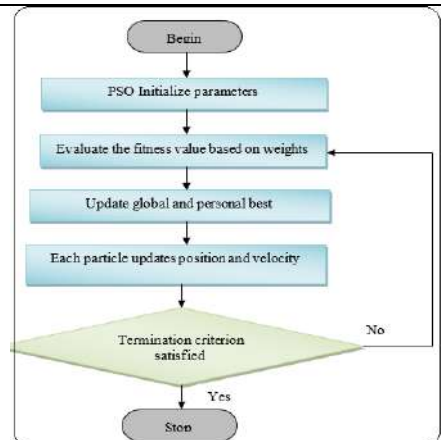


Figure 2: IWPSO architecture

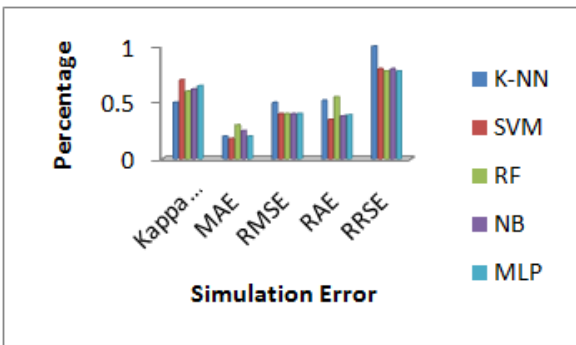


Figure 3: Simulated inaccuracy in the absence of optimization

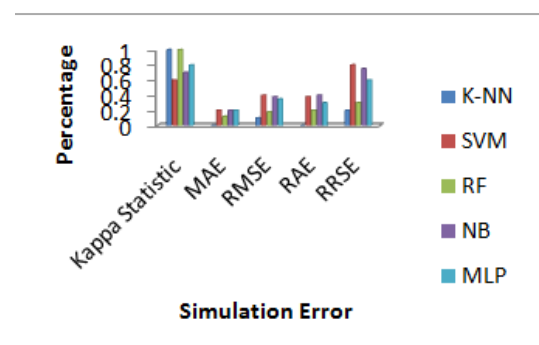


Figure 4: Simulation error optimized by FCBFs-IWPSO





A Partial Backlog Inventory Model for Perishable Items with Linear Holding Cost, Time and Selling Price Dependent Split Demand and Time-Varying Deterioration

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ABSTRACT

This article introduces an inventory optimization model to maximize total profit by considering various complex factors such as split demand, time-linked deterioration, linear holding cost function, time-dependent shortage, and partial backlog considerations. This holistic approach to decision-making in inventory management is illustrated through a numerical example and sensitivity analysis, demonstrating how system limits influence optimization outcomes. The model provides a comprehensive tool to enhance inventory management practices and optimize profitability, employing a computational algorithm and theorem to achieve maximal profit and assess concavity. Sensitivity analysis explores parameter variations affecting economic order quantity (EOQ), ideal ordering time, overall profit, etc., with MATLAB facilitating graphical visualization of model parameter relationships.

Keywords: EOQ, Price and time-dependent split demand, shortage, time-varying deterioration, linear holding cost, partial backlogging.





INTRODUCTION

The research delves into crucial aspects of inventory management, particularly in the context of the challenges posed by the COVID-19 pandemic. The disruption of transportation and distribution networks and increased health-related concerns have underscored the need for resilient inventory management strategies. Emphasis on price-dependent demand and the impact of product expiration dates on consumer behaviour demonstrates a keen understanding of market dynamics. Acknowledging the fluctuating decay rates of perishable goods over time, a critical factor in inventory management often overlooked in traditional models is addressed. Considering both shortage and non-shortage scenarios in this inventory model adds depth and practical relevance to this research. They recognize the changing nature of holding costs over time and model them as a linearly increasing function, accounting for the dynamic nature of inventory management decisions. The research is well-grounded in theoretical concepts while also being attuned to the practical realities of supply chain operations in a post-pandemic world. The study gives the potential to optimize inventory management strategies, ultimately helping businesses navigate uncertainties and maximize profits.

LITERATURE REVIEW

This study utilizes four lines of inventory theory research rooted in Harris's economic quantity model, including time-dependent linear holding costs, price and time-dependent split demand, time-varying deteriorating items with expiration dates, and item shortages within the inventory cycle.

Inventory models for decaying items

Inventory management aims to optimize the balance between inventory costs and service levels. A crucial consideration in inventory management is the deterioration of items over time, which can significantly impact inventory decisions and expenses. This study addresses inventory models with time-dependent deterioration, exploring various approaches and factors influencing decision-making processes. Ghare and Schrader (1963) proposed a fundamental model for exponentially decaying inventory, laying the groundwork for subsequent research. Covert and Philip (1973) extended this work by introducing an Economic Order Quantity (EOQ) model for items with Weibull distribution deterioration, highlighting the importance of considering specific deterioration patterns in inventory management. Subsequent studies, such as those by Ghosh and Chaudhuri (2006) and Sarkar and Sarkar (2013), expanded upon these models by incorporating multiple factors like quadratic demand, time-proportional deterioration, shortages, and stock-dependent demand. These studies emphasized the importance of addressing various factors simultaneously to model real-world inventory systems accurately. Further advancements, as demonstrated by Prasad and Mukherjee (2016) and Shah, Chaudhari, and Jani (2017), introduced optimal inventory models considering time-varying deterioration rates, preservation technology, selling price, and trade credit-dependent demand, providing comprehensive frameworks for decision-making in supply chain contexts. Recent studies, including Rahman and Uddin (2020), Sayal et al. (2022), and Khare and Sharma (2022), continue to enhance understanding by addressing more complex dynamics such as time-dependent demand functions, uncertainty, and variable costs, highlighting the need to adapt inventory strategies in dynamic and uncertain environments. Rana and Singh (2023) showcased the integration of sustainability considerations into inventory decision-making processes, underlining the importance of incorporating broader organizational goals into inventory management strategies in the last year.

Inventory models for time-varying holding cost

This research challenges the traditional assumption of constant holding costs in inventory management, particularly for perishable and deteriorating products. It stresses the necessity for dynamic inventory models that can accurately incorporate time-varying holding costs and demand dependencies to optimize inventory management effectively. This study proposes inventory models with time-varying linear holding costs. Mishra (2014) introduces a deteriorating inventory model that considers controllable deterioration rates and varying holding costs, emphasizing



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the importance of adapting to changing demand and expenses. Alfares and Ghaithan (2016) present an inventory and pricing model incorporating price-dependent demand, fluctuating holding costs, and quantity discounts, offering insights into optimizing inventory levels and pricing strategies. Tripathi and Tomar (2018) developed an EOQ model that considers quadratic time-sensitive demand and parabolic time-linked holding costs with salvage value, highlighting the significance of time-sensitive demand and salvage value. Singh, Sharma, and Singh (2019) devise an inventory model for deteriorating items with incremental holding costs under partial backlogging, providing a comprehensive framework for efficient inventory management. Khan et al. (2020) investigate inventory models for perishable items with time-dependent holding costs under advanced payments and demand dependent on advertising frequency, addressing the complexity of perishable inventory management. They further propose time-dependent inventory management with hybrid cash-advance payment for varying holding costs, deterioration, and shortages, tackling practical challenges in inventory management in 2022. Sivashankari and Vijayakumar (2023) study the impact of stock-dependent demand in EOQ models under different holding cost structures, emphasizing the importance of choosing suitable structures for optimal inventory management in the last year.

Inventory models for price and time-dependent demand

Integrating time and price dependencies within demand modelling is a critical and complex element of inventory management. This study approaches inventory models with time and price-dependent demand, highlighting different approaches and their implications for decision-making. Whitin (1955) and Donaldson (1977) laid the groundwork for considering price theory in inventory control, emphasizing the impact of pricing strategies on demand dynamics. Mondal, Bhunia, and Maiti (2003) and You (2005) introduced inventory systems and policies that consider price-dependent demand, recognizing the sensitivity of demand to pricing strategies and temporal factors. Avinadav, Herbon, and Spiegel (2013) investigated optimal inventory policies for perishable items with demand functions sensitive to both price and time, acknowledging the perishable nature of goods and the influence of pricing and temporal factors on demand. Further, Hossen et al. (2016) extended this research by incorporating fuzzy-valued inventory costs under inflation, considering demand sensitivity to price and time. In the same year, Kumar optimized inventory models for deteriorating items with price and time-dependent demand, aligning inventory decisions with fluctuating demand patterns influenced by pricing strategies.

Suryanarayana et al. (2019) proposed an EOQ model considering time-varying holding costs with time and selling price-dependent demand for deteriorating items under partial backlogging, addressing complex dynamics in inventory management. Narang and De (2023) recently introduced an imperfect production-inventory model for reworked items with advertisement, time, and price-dependent demand, utilizing genetic algorithms to optimize inventory decisions under uncertainties. Babai et al. considered optimal ordering quantity under stochastic time-dependent price and demand, offering solutions to manage uncertainties in demand and pricing in the same year. Presently, Shee and Chakrabarti (2024) have developed an inventory model for deteriorating products with lead time and selling price-sensitive demand, addressing operational challenges in managing inventory considering price and temporal dependencies in demand. Nautiyal (2024) proposed an EOQ model with nonlinear holding costs and hybrid demand, acknowledging the influence of mixed demand patterns on inventory decisions. Kumar, Yadav, and Yadav (2024) presented a two-storage production inventory optimization model for deteriorating items with time and selling price-dependent demand, utilizing flower pollination optimization to manage the dynamic nature of demand. These studies demonstrate the importance of integrating time and price dependencies in demand modelling for effective inventory management.

Inventory models for shortages

This article focuses on inventory models addressing shortages, which is critical for preventing stockouts and improving customer satisfaction. Key findings from various studies include Ghosh and Chaudhuri (2006), who introduced EOQ models that consider shortages in all cycles to balance inventory and customer service levels. Sarkar and Sarkar (2013) extended inventory models to include partial backlogging, time-varying deterioration, and stock-dependent demand. Prasad and Mukherjee Investigated optimal inventory models under stock and time-dependent demand with shortages in 2016. Shah, Chaudhari, and Jani (2017) explore optimal policies for time-varying





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deteriorating items with preservation technology in a supply chain context. Rahman and Uddin (2020) analyzed inventory models considering time-dependent demand functions. In recent years, Sayal et al. (2022) have addressed optimizing inventory models for deteriorating items with time-varying holding costs under uncertainty. Khare and Sharma (2022) investigated the effects of time-deteriorating rates with variable costs on inventory models. Rana and Singh (2023) also discussed sustainable production inventory models considering shortage management. Narang and De (2023) introduced imperfect production-inventory models for reworked items, considering shortages. They presented two-storage production inventory models for deteriorating items, emphasizing efficient shortage management at Kumar, Yadav, and Yadav in 2024. These studies highlight the significance of approached shortages in inventory modelling for effective inventory management strategies.

Research questions

The research questions identified based on the provided results are as follows:

1. What are the optimum selling price, cycle time, and zero inventory period to maximize the retailer's profit?
2. How does the selling price impact the inventory cycle, stock levels, and product purchases?
3. What is the most effective technique to manage inventory stockout periods and the last sale cost?

To address these questions, a flexible model is required to handle scenarios involving selling price-dependent demand shortages for deteriorating items with partial backlogs and time-varying holding costs within the supply chain environment. The presented inventory optimization model offers a more comprehensive approach to decision-making processes in inventory management by addressing multiple complexities inherent in the system. It provides a valuable tool for businesses seeking to improve their inventory management practices and optimize their profitability.

FORMULATION OF THE PROBLEM

Assumptions

- The inventory system for a single item is considered.
- The cost of holding a unit product for a specific duration is directly proportional to its storage time, consisting of a constant part (α) and a linearly increasing part (β) that increases with storage duration. (ie) $H(T) = \alpha + \beta t$, $\alpha \geq 0$ and $\beta \geq 0$.
- The degradation rate $\theta(t)$ within the period $[0, t_1]$ is time-linked, with items deteriorating with a specific expiry date. $\theta(t) = \theta t$, $0 \leq \theta < 1$.
- The planning horizon is infinite.
- Demand rate $D(t)$ is time-dependent and follows a split pattern during a cycle. $D(t) = \begin{cases} a - bp + ct, & 0 \leq t < t_1 \\ a + ct, & t_1 < t \leq T \end{cases}$ where a represents the scaling parameter, b denotes the price sensitivity parameter and c is the rate of change of demand.
- The shortages are permissible and are partially backlogged. The demand is backordered in a decreasing manner, with the fraction as $B(T - t) = \frac{1}{1 + \delta(T - t)}$, $T - t$ representing the waiting time until the next replenishing point, where the waiting time is greater than zero, and δ is the backorder parameter.
- The replenishment rate is instantaneous, and the item is replenished periodically (each inventory cycle).
- Lead time is zero.

Notations

- $q(t)$ - Inventory level at instant 't'
 A - Cost of placing an order
 k - Unit cost of an item
 p - Unit cost of Sale of an item
 d -Unit cost of deteriorating item





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- s - Shortage cost for backlogged items per unit per cycle
- l - The unit cost of the last Sale
- t₁ - Duration of physical stock entering the storage, shortages occurring just after t₁
- T - Length of cycle time or scheduled period.
- OC - Ordering cost
- PC - Purchasing cost
- DC - deterioration cost
- SC - Shortage cost
- HC - Holding cost
- LSC - Lost sale cost
- SR - Sales Revenue
- Q - (S+R) The order size per cycle.
- Z(p,t₁T) - The total cost of the inventory system.
- TP(p,t₁,T) - The total profit of the inventory cycle.

Mathematical Formulation

At the start of a cycle, an order of S units of an item arrives in stock, which is doesn't used to satisfy backlog demand. The goods are consumed to meet client demand and degrade at a linear, time-varying rate. At time t = t₁, the inventory level reaches zero due to customer demand and deterioration. Shortly after, shortages build up, depending on customer wait times. The entire inventory system is replicated as a new order is placed. The governing differential equations can display the inventory level at any point t₁ [0, T].

$$\frac{dq_1(t)}{dt} + \theta(t)q_1(t) = -D_1(t), \quad 0 \leq t < t_1 \tag{1}$$

q₁(t₁) = 0 at t = t₁, with this boundary condition.

When stock runs out during the interval [t₁, T], the differential equation can be applied to modelling the inventory.

$$\frac{dq_2(t)}{dt} = \frac{-D_2(t)}{1 + \delta(T-t)}, \quad t_1 < t \leq T \tag{2}$$

Solution of (1) and (2) are

$$q_1(t) = (a - bp) \left(t_1 + \theta \left(\frac{t_1^3}{6} - \frac{t_1 t^2}{2} \right) + \theta^2 \left(\frac{t_1^5}{40} - \frac{t_1^3 t^2}{12} + \frac{t_1 t^4}{8} \right) \right) - (a - bp) \left(t - \frac{\theta t^3}{3} + \frac{\theta^2 t^5}{15} \right) + c \left(\frac{t_1^2}{2} + \theta \left(\frac{t_1^4}{8} - \frac{t_1^2 t^2}{4} \right) + \theta^2 \left(\frac{t_1^6}{48} - \frac{t_1^4 t^2}{16} + \frac{t_1^2 t^4}{16} \right) \right) - c \left(\frac{t^2}{2} - \frac{\theta t^4}{8} + \frac{\theta^2 t^6}{48} \right) \tag{3}$$

$$q_2(t) = \frac{1}{\delta} \left\{ \left(a + \frac{c}{\delta} + cT \right) \ln(1 + \delta(T-t)) - c(T-t) \right\} - R \tag{4}$$

with S = q₁(0) and -R = q₂(T), q₂(t₁) = 0 and Q = S+R

$$Q = (a - bp) \left(t_1 + \frac{\theta t_1^3}{6} + \frac{\theta^2 t_1^5}{40} \right) + c \left(\frac{t_1^2}{2} + \frac{\theta t_1^4}{8} + \frac{\theta^2 t_1^6}{48} \right) + \frac{1}{\delta} \left\{ \left(a + \frac{c}{\delta} + cT \right) \ln(1 + \delta(T-t_1)) - c(T-t_1) \right\} \tag{5}$$

- (i) The retailer performs various tasks like creating purchase orders, shipping, inspecting, handling products, storing, and reporting, considering total ordering costs (OC) as constant expenses every time a product is purchased.
- (ii) Retailers establish a fixed price per unit for the cycle duration to satisfy client demand. Each cycle's purchasing cost is calculated using the purchase cost per unit (k), where k stands for the unit item and Q for the overall amount purchased.
- (iii) Number of deteriorating items during [0, t₁] is





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$$S - \int_0^{t_1} (a - bp + ct)dt = (a - bp) \left(\frac{\theta t_1^3}{6} + \frac{\theta^2 t_1^5}{40} \right) + c \left(\frac{\theta t_1^4}{8} + \frac{\theta^2 t_1^6}{48} \right) \tag{6}$$

(iv) The cost of degradation is the loss resulting from deterioration, damage, and obsolescence, decreasing between $[0, t_1]$ times, with the original stock remaining at the end.

$$DC = d \left\{ S - \int_0^{t_1} (a - bp + ct)dt \right\} = d \left\{ (a - bp) \left(\frac{\theta t_1^3}{6} + \frac{\theta^2 t_1^5}{40} \right) + c \left(\frac{\theta t_1^4}{8} + \frac{\theta^2 t_1^6}{48} \right) \right\} \tag{7}$$

(v) Retailers maintain sufficient product inventories during planning to meet customer expectations, with technology reducing costs by allowing access to store inventory between times $[0, t_1]$.

$$HC = \int_0^{t_1} (\alpha + \beta t)q_1(t)dt = \alpha \left\{ (a - bp) \left(\frac{t_1^2}{2} + \frac{\theta t_1^4}{12} + \frac{\theta^2 t_1^6}{90} \right) + c \left(\frac{t_1^3}{3} + \frac{\theta t_1^5}{15} + \frac{\theta^2 t_1^7}{105} \right) \right\} \\ + \beta \left\{ (a - bp) \left(\frac{t_1^3}{6} + \frac{\theta t_1^5}{40} + \frac{\theta^2 t_1^7}{336} \right) + c \left(\frac{t_1^4}{8} + \frac{\theta t_1^6}{48} + \frac{\theta^2 t_1^8}{384} \right) \right\} \tag{8}$$

(vi) The cost of a shortage includes wasted time, deformation, theft, obsolescence, and equipment servicing fees. Unmet demand in the time range from t_1 to T results in a shortfall cost represented mathematically as SC.

$$SC = s \int_{t_1}^T (-q_2(t))dt = s \left\{ \frac{1}{\delta^2} \left(a + \frac{c}{\delta} + cT \right) \left(\delta(T - t_1) - \ln(1 + \delta(T - t_1)) \right) - \frac{c}{2\delta} (T - t_1)^2 \right\} \tag{9}$$

(vii) Contrarily, only some customers possess the same characteristics. Some shoppers will go to a different store to fulfil their needs. This loss thus has a monetary value known as opportunity cost. The mathematical representation of opportunity cost is as follows:

$$LSC = l \int_{t_1}^T (a + ct) \left(1 - \frac{1}{1 + \delta(T - t)} \right) dt \\ = l \left\{ a(T - t_1) + \frac{c}{2}(T^2 - t_1^2) - \frac{1}{\delta} \left[\left(a + \frac{c}{\delta} + cT \right) \ln(1 + \delta(T - t_1)) - c(T - t_1) \right] \right\} \tag{10}$$

(viii) The sales income for the entire cycle length is calculated using the item's selling price (p) and favourable stock period (t_1) with demand $D(t)$.

Thus, the total cost per cycle is $Z(T, t_1) = (OC + PC + DC + HC + SC + LSC) / T$

$$Z(p, t_1, T) = \frac{1}{T} \left\{ A + kQ + d \left[(a - bp) \left(\frac{\theta t_1^3}{6} + \frac{\theta^2 t_1^5}{40} \right) + c \left(\frac{\theta t_1^4}{8} + \frac{\theta^2 t_1^6}{48} \right) \right] \right. \\ + \alpha \left[(a - bp) \left(\frac{t_1^2}{2} + \frac{\theta t_1^4}{12} + \frac{\theta^2 t_1^6}{90} \right) + c \left(\frac{t_1^3}{3} + \frac{\theta t_1^5}{15} + \frac{\theta^2 t_1^7}{105} \right) \right] \\ + \beta \left[(a - bp) \left(\frac{t_1^3}{6} + \frac{\theta t_1^5}{40} + \frac{\theta^2 t_1^7}{336} \right) + c \left(\frac{t_1^4}{8} + \frac{\theta t_1^6}{48} + \frac{\theta^2 t_1^8}{384} \right) \right] \\ + s \left[\frac{1}{\delta^2} \left(a + \frac{c}{\delta} + cT \right) \left(\delta(T - t_1) - \ln(1 + \delta(T - t_1)) \right) - \frac{c}{2\delta} (T - t_1)^2 \right] \\ \left. + l \left[a(T - t_1) + \frac{c}{2}(T^2 - t_1^2) - \frac{1}{\delta} \left[\left(a + \frac{c}{\delta} + cT \right) \ln(1 + \delta(T - t_1)) - c(T - t_1) \right] \right] \right\} \tag{11}$$

Thus, the total profit along an inventory cycle is





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$$TP(p,t_1,T) = ((p-k)Q - (OC+DC + HC + SC+LSC))/T \tag{12}$$

$$TP(p,t_1,T) = \frac{1}{T} \left\{ (p-k)Q - A - d \left[(a-bp) \left(\frac{\theta t_1^3}{6} + \frac{\theta^2 t_1^5}{40} \right) + c \left(\frac{\theta t_1^4}{8} + \frac{\theta^2 t_1^6}{48} \right) \right] \right. \\ - \alpha \left[(a-bp) \left(\frac{t_1^2}{2} + \frac{\theta t_1^4}{12} + \frac{\theta^2 t_1^6}{90} \right) + c \left(\frac{t_1^3}{3} + \frac{\theta t_1^5}{15} + \frac{\theta^2 t_1^7}{105} \right) \right] \\ - \beta \left[(a-bp) \left(\frac{t_1^3}{6} + \frac{\theta t_1^5}{40} + \frac{\theta^2 t_1^7}{336} \right) + c \left(\frac{t_1^4}{8} + \frac{\theta t_1^6}{48} + \frac{\theta^2 t_1^8}{384} \right) \right] \\ - s \left[\frac{1}{\delta^2} \left(a + \frac{c}{\delta} + cT \right) \left(\delta(T-t_1) - \ln(1 + \delta(T-t_1)) \right) - \frac{c}{2\delta} (T-t_1)^2 \right] \\ \left. - l \left[a(T-t_1) + \frac{c}{2} (T^2 - t_1^2) - \frac{1}{\delta} \left(\left(a + \frac{c}{\delta} + cT \right) \ln(1 + \delta(T-t_1)) - c(T-t_1) \right) \right] \right\} \tag{13}$$

Considering the total inventory cost, the nonlinear optimization problem is written as

$$\text{Maximize } TP(p,t_1,T) = \frac{X(p,t_1,T)}{T}, \text{ Subject to } (T-t_1) \geq 0 \text{ and } p > 0$$

where

$$X(p,t_1,T) = \left\{ (p-k)Q - A - d \left[(a-bp) \left(\frac{\theta t_1^3}{6} + \frac{\theta^2 t_1^5}{40} \right) + c \left(\frac{\theta t_1^4}{8} + \frac{\theta^2 t_1^6}{48} \right) \right] \right. \\ - \alpha \left[(a-bp) \left(\frac{t_1^2}{2} + \frac{\theta t_1^4}{12} + \frac{\theta^2 t_1^6}{90} \right) + c \left(\frac{t_1^3}{3} + \frac{\theta t_1^5}{15} + \frac{\theta^2 t_1^7}{105} \right) \right] \\ - \beta \left[(a-bp) \left(\frac{t_1^3}{6} + \frac{\theta t_1^5}{40} + \frac{\theta^2 t_1^7}{336} \right) + c \left(\frac{t_1^4}{8} + \frac{\theta t_1^6}{48} + \frac{\theta^2 t_1^8}{384} \right) \right] \\ - s \left[\frac{1}{\delta^2} \left(a + \frac{c}{\delta} + cT \right) \left(\delta(T-t_1) - \ln(1 + \delta(T-t_1)) \right) - \frac{c}{2\delta} (T-t_1)^2 \right] \\ \left. - l \left[a(T-t_1) + \frac{c}{2} (T^2 - t_1^2) - \frac{1}{\delta} \left(\left(a + \frac{c}{\delta} + cT \right) \ln(1 + \delta(T-t_1)) - c(T-t_1) \right) \right] \right\} \tag{14}$$

Computational steps to obtain the optimal Solution

Step 1: Set the parameters to a, b, c, A, α, β, δ, s, d, k, l and θ.

Step 2: The following costs compose the total profit : selling price, ordering cost, purchasing cost, carrying cost, degradation cost, backorder cost and last sale cost. The total profit function is defined in the equation (13).

Step 3: Taking the first-order and the second-order partial differentiation for the equation (13) with respect to p, t₁ and T, the equations $\frac{\partial TP(p,t_1,T)}{\partial p}$, $\frac{\partial TP(p,t_1,T)}{\partial t_1}$ and $\frac{\partial TP(p,t_1,T)}{\partial T}$ are obtained.

Step 4: By resolving equations $\frac{\partial TP(p,t_1,T)}{\partial p} = 0$, $\frac{\partial TP(p,t_1,T)}{\partial t_1} = 0$ and $\frac{\partial TP(p,t_1,T)}{\partial T} = 0$, the optimal values of p, t₁ and T are obtained.

Step 5: Check whether the optimum values satisfy the systematic inventory conditions

$$\frac{\partial^2 TP(p,t_1,T)}{\partial p^2} < 0, \frac{\partial^2 TP(p,t_1,T)}{\partial t_1^2} < 0, \frac{\partial^2 TP(p,t_1,T)}{\partial T^2} < 0 \text{ and}$$





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$$\begin{aligned} & \left(\frac{\partial^2 TP(p, t_1, T)}{\partial p^2} \right) \left(\left(\frac{\partial^2 TP(p, t_1, T)}{\partial t_1^2} \right) \left(\frac{\partial^2 TP(p, t_1, T)}{\partial T^2} \right) - \left(\frac{\partial^2 TP(p, t_1, T)}{\partial T \partial t_1} \right)^2 \right) \\ & - \left(\frac{\partial^2 TP(p, t_1, T)}{\partial t_1 \partial p} \right)^2 \left(\frac{\partial^2 TP(p, t_1, T)}{\partial T^2} \right) - \left(\frac{\partial^2 TP(p, t_1, T)}{\partial T \partial p} \right) \left(\frac{\partial^2 TP(p, t_1, T)}{\partial t_1^2} \right) \\ & + 2 \left(\frac{\partial^2 TP(p, t_1, T)}{\partial T \partial t_1} \right) \left(\frac{\partial^2 TP(p, t_1, T)}{\partial t_1 \partial p} \right) \left(\frac{\partial^2 TP(p, t_1, T)}{\partial T \partial p} \right) < 0 \end{aligned}$$

Step 6: The Hessian matrix of second derivatives is used to determine the extremum's min or max, and the maximality of the total cost function, guaranteed by its concavity, is represented by the Hessian matrix for the entire cost function $TP(p, t_1, T)$.

$$H(p, t_1, T) = \begin{vmatrix} \frac{\partial^2 X(p, t_1, T)}{\partial p^2} & \frac{\partial^2 X(p, t_1, T)}{\partial t_1 \partial p} & \frac{\partial^2 X(p, t_1, T)}{\partial T \partial p} \\ \frac{\partial^2 X(p, t_1, T)}{\partial p \partial t_1} & \frac{\partial^2 X(p, t_1, T)}{\partial t_1^2} & \frac{\partial^2 X(p, t_1, T)}{\partial T \partial t_1} \\ \frac{\partial^2 X(p, t_1, T)}{\partial p \partial T} & \frac{\partial^2 X(p, t_1, T)}{\partial t_1 \partial T} & \frac{\partial^2 X(p, t_1, T)}{\partial T^2} \end{vmatrix}$$

The Hessian matrix H controls concavity, ensuring the total profit cost of the inventory function. The optimal values of p, t₁ and T maximize the inventory system's complete profit cost time unit. The real-valued function $TP(p, t_1, T)$ is strictly concave, and the non-negative differentiable.

Step 7: The optimal values of p, t₁ and T are used to determine the best order quantity without shortage, with the highest profit and maximum inventory cost.

Logical effects

To maximize $TP(p, t_1, T)$, our results aim to identify the ideal value for p, t₁ and T. The function's maximum total profit maximization requirements are provided by $\frac{\partial TP(p, t_1, T)}{\partial p} = 0$, $\frac{\partial TP(p, t_1, T)}{\partial t_1} = 0$ and $\frac{\partial TP(p, t_1, T)}{\partial T} = 0$.

Theorem 1

The objective function value, a pseudo-concave function in p, reaches its global maximum with fixed parameters, resulting in a unique maximum solution in p.

Proof

The equation X should be differentiated with respect to p, so get

$$\frac{\partial X(p, t_1, T)}{\partial p} = (p - k) \frac{\partial Q}{\partial p} + Q + db \left(\frac{\theta t_1^3}{6} + \frac{\theta^2 t_1^5}{40} \right) + \alpha b \left(\frac{t_1^2}{2} + \frac{\theta t_1^4}{12} + \frac{\theta^2 t_1^6}{90} \right) + \beta b \left(\frac{t_1^3}{6} + \frac{\theta t_1^5}{40} + \frac{\theta^2 t_1^7}{336} \right) \tag{15}$$

$$\text{Differentiate the equation X with respect to p again } \frac{\partial^2 X(p, t_1, T)}{\partial p^2} = \frac{2\partial Q}{\partial p} < 0 \tag{16}$$

$$\text{According to the equation above, } \frac{\partial^2 TP(p, t_1, T)}{\partial p^2} < 0 \tag{17}$$

The function $TP(p, t_1, T)$ is strictly concave in p, and there is a unique optimal solution p by taking the first-order derivative and setting the result to zero.





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$$\frac{\partial TP(p, t_1, T)}{\partial p} = \frac{1}{T} \frac{\partial X(p, t_1, T)}{\partial p} = 0 \tag{18}$$

Using some of the implications from the above equation

$$p = \frac{1}{2b \left(t_1 + \frac{\theta t_1^3}{6} + \frac{\theta^2 t_1^5}{40} \right)} \left\{ (a + bk) \left(t_1 + \frac{\theta t_1^3}{6} + \frac{\theta^2 t_1^5}{40} \right) + c \left(\frac{t_1^2}{2} + \frac{\theta t_1^4}{8} + \frac{\theta^2 t_1^6}{48} \right) + db \left(\frac{\theta t_1^3}{6} + \frac{\theta^2 t_1^5}{40} \right) \right. \\ \left. + \alpha b \left(\frac{t_1^2}{2} + \frac{\theta t_1^4}{12} + \frac{\theta^2 t_1^6}{90} \right) + \beta b \left(\frac{t_1^3}{6} + \frac{\theta t_1^5}{40} + \frac{\theta^2 t_1^7}{336} \right) + \frac{1}{\delta} \left[\left(a + \frac{c}{\delta} + cT \right) \ln(1 + \delta(T - t_1)) - c(T - t_1) \right] \right\} \tag{19}$$

Equation (19) demonstrates that p depends on both t₁ and T.

Theorem 2

A singular maximum solution in t₁ is produced when the objective function value, a pseudo-concave function in t₁, finds its global maximum with fixed parameters.

Proof

It is possible to differentiate the equation with regard to t₁, leading to

$$\frac{\partial X(p, t_1, T)}{\partial t_1} = (p - k) \frac{\partial Q}{\partial t_1} - d \left[(a - bp) \left(\frac{\theta t_1^2}{2} + \frac{\theta^2 t_1^4}{8} \right) + c \left(\frac{\theta t_1^3}{2} + \frac{\theta^2 t_1^5}{8} \right) \right] \\ - \alpha \left[(a - bp) \left(t_1 + \frac{\theta t_1^3}{3} + \frac{\theta^2 t_1^5}{15} \right) + c \left(t_1^2 + \frac{\theta t_1^4}{3} + \frac{\theta^2 t_1^6}{15} \right) \right] \\ - \beta \left[(a - bp) \left(\frac{t_1^2}{2} + \frac{\theta t_1^4}{8} + \frac{\theta^2 t_1^6}{48} \right) + c \left(\frac{t_1^3}{2} + \frac{\theta t_1^5}{8} + \frac{\theta^2 t_1^7}{48} \right) \right] \\ - s \left[\frac{1}{\delta} \left(a + \frac{c}{\delta} + cT \right) \left(\frac{1}{1 + \delta(T - t_1)} - 1 \right) + \frac{c}{\delta} (T - t_1) \right] - l \left[-a - ct_1 + \frac{c}{\delta} + \frac{a + \frac{c}{\delta} + cT}{1 + \delta(T - t_1)} \right] \tag{20}$$

Differentiate equation X from t₁ once more to get this result.

$$\frac{\partial^2 X(p, t_1, T)}{\partial t_1^2} = (p - k) \frac{\partial^2 Q}{\partial t_1^2} - d \left[(a - bp) \left(\theta t_1 + \frac{\theta^2 t_1^3}{2} \right) + c \left(\frac{3\theta t_1^2}{2} + \frac{5\theta^2 t_1^4}{8} \right) \right] \\ - \alpha \left[(a - bp) \left(1 + \theta t_1 + \frac{\theta^2 t_1^2}{3} \right) + c \left(2t_1 + \frac{4\theta t_1^3}{3} + \frac{2\theta^2 t_1^5}{5} \right) \right] \\ - \beta \left[(a - bp) \left(t_1 + \frac{\theta t_1^3}{2} + \frac{\theta^2 t_1^5}{8} \right) + c \left(\frac{3t_1^2}{2} + \frac{5\theta t_1^4}{8} + \frac{7\theta^2 t_1^6}{48} \right) \right] \\ - s \left[\frac{a + \frac{c}{\delta} + cT}{(1 + \delta(T - t_1))^2} - \frac{c}{\delta} \right] - l \left[-c + \frac{\delta \left(a + \frac{c}{\delta} + cT \right)}{(1 + \delta(T - t_1))^2} \right] < 0 \tag{21}$$

The equation above demonstrates that $\frac{\partial^2 TP(p, t_1, T)}{\partial t_1^2} < 0,$ (22)





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By evaluating the function's first-order derivative, it is possible to identify the best solution for the function TP(p, t₁, T), which is strictly concave in t₁.

$$\frac{\partial TP(p, t_1, T)}{\partial t_1} = -\frac{X(p, t_1, T)}{T^2} + \frac{1}{T} \frac{\partial X(p, t_1, T)}{\partial t_1} = 0 \tag{23}$$

$$X(p, t_1, T) = T \frac{\partial X(p, t_1, T)}{\partial t_1} \tag{24}$$

The unique value of t₁ can be obtained by utilizing the equation's implications.

Theorem 3

When the objective function value, a pseudo-concave function in T, reaches its global maximum with fixed parameters, a solitary maximum solution in T is produced.

Proof

The equation X can be differentiated with respect to T, resulting in

$$\begin{aligned} \frac{\partial X(p, t_1, T)}{\partial T} = & (p-k) \frac{\partial Q}{\partial T} - s \left[\frac{1}{\delta^2} \left(\left(a + \frac{c}{\delta} + cT \right) \left(\delta - \frac{\delta}{1 + \delta(T-t_1)} \right) + c(\delta(T-t_1) - \ln(1 + \delta(T-t_1))) \right) - \frac{c}{\delta}(T-t_1) \right] \\ & - l \left[a + cT - \frac{1}{\delta} \left(\frac{\delta \left(a + \frac{c}{\delta} + cT \right)}{1 + \delta(T-t_1)} + c \ln(1 + \delta(T-t_1)) - c \right) \right] \end{aligned} \tag{25}$$

To get, further differentiate X from T

$$\frac{\partial^2 X(p, t_1, T)}{\partial T^2} = (p-k) \frac{\partial^2 Q}{\partial T^2} - s \left[\left(\frac{a + \frac{c}{\delta} + cT}{(1 + \delta(T-t_1))^2} \right) - \frac{c}{\delta} \right] - l \left[c - \frac{(1 + \delta(T-t_1))c - \delta \left(a + \frac{c}{\delta} + cT \right)}{(1 + \delta(T-t_1))^2} - \frac{1}{(1 + \delta(T-t_1))} \right] < 0 \tag{26}$$

As indicated by the equation above, $\frac{\partial^2 TP(p, t_1, T)}{\partial T} < 0$ (27)

The optimum solution for the function TP(p, t₁, T), which is strictly concave in T, may be found by analyzing the function's first-order derivative.

$$\frac{\partial TP(p, t_1, T)}{\partial T} = -\frac{X(p, t_1, T)}{T^2} + \frac{1}{T} \frac{\partial X(p, t_1, T)}{\partial T} = 0 \tag{28}$$

$$X(p, t_1, T) = T \frac{\partial X(p, t_1, T)}{\partial T} \tag{29}$$

Some of the implications from the above equation are used to obtain the unique value of T.

Numerical Computation and Evaluation of Sensitivity

The proposed model is validated using numerical data and sensitivity analysis, considering all potential parameters. The data provided in this study is used to demonstrate the outcomes of the model developed numerically. Consider the values a=400 units per year, b=4 units per year, c=10units per year, A=₹10per order, k=₹40 per year, d=₹20 per year, s=₹15 per unit, l=₹15per year, α=₹1.5 per unit, β=0.1, δ=0.06 and θ=0.85. Taking the above data, determine the optimal values as TP=₹9313.73, p=₹97.76, t₁=2.4304, T=4.6404, S=904.0953, R=151.3537 and Hessian value is -8.5517 < 0 in appropriate units.



**Vanjikkodi and Pankajam****Observations of the table and figures**

Observations of the table are various relationships between different parameters and their effects on selling price, stock value, inventory cycle time, order quantity, shortage period quantity, and overall profit in an inventory management context. These relationships are crucial for understanding how parameter changes impact inventory management decisions. Here's a summary of the relationships described:

- The selling price rises if the constant demand (a), dynamic demand parameter (c), purchase cost (k), depreciating cost (d), and constant holding cost (α) all go up. The selling price is dropped while the other elements are raised. However, the selling price will stay the same if the variable in time holding cost parameter is raised.
- The stock's value rises over time if the price-sensitive parameter (b), purchase cost (k), degrading cost (d), constant holding cost (α), and time-varying holding cost parameter (β) are all increased. As the goods run time gets shorter, the remaining parameters get bigger.
- The constant demand (a), time-varying demand parameter (c), deteriorating cost (d), constant holding cost (α), and duration-varying holding cost parameter (β) all cause an increase in the inventory cycle time. While the other parameters are increased, the cycle time is decreased.
- If the constant demand (a), time-dependent demand parameter (c), deteriorating cost (d), constant holding cost (α), and time-varying holding cost parameter (β) are increased, the order quantity for the period without shortage increases. While the other characteristics are increased, the order quantity without a deficit time is decreased.
- The requested quantity for the shortage period rises if the constant demand (a), price-sensitive parameter (b), backlog parameter (δ), deteriorating cost (d), constant holding cost (α), and that change over time holding cost parameter (β) is raised. The order quantity during a shortage time is lowered while the other parameters are raised.
- The overall profit for the inventory rises when the constant demand (a), time-varying demand parameter (c), and deterioration parameter (θ) all grow. The overall profit price is dropped while the other parameters are raised.

Constant Demand (a) involves retailers receiving a forecast and efficiently managing inventory levels to meet this baseline demand. Dynamic Demand Parameter (c) prompts retailers to analyze previous cycle sales data and market trends to comprehend demand patterns and adjust inventory levels accordingly. Purchase Cost (k) advises retailers to negotiate favourable pricing terms with suppliers and explore opportunities to reduce procurement costs through bulk purchasing, strategic sourcing, or alternative suppliers. Depreciating Cost (d) underscores the importance of closely managing perishable or time-sensitive inventory to minimize losses due to deterioration. Constant Holding Cost (α) emphasizes the need for retailers to optimize inventory turnover rates to reduce holding costs while ensuring adequate stock availability. Variable in Time Holding Cost Parameter (β) encourages retailers to analyze the cost implications of holding inventory for different durations and adjust inventory management strategies accordingly. Price-Sensitive Parameter (b) fosters retailers to conduct price sensitivity analyses to understand how customers respond to price changes and adjust pricing strategies accordingly. Backlog Parameter (δ) outlines the importance of retailers effectively managing backlog by prioritizing orders based on customer preferences, inventory availability, and order fulfilment capabilities. By considering and effectively managing these parameters, retailers can optimize their inventory management practices, improve operational efficiency, and enhance profitability in the competitive retail landscape. The observation highlights that demand dynamics, purchase costs, holding costs, deterioration costs, and time-related parameters significantly impact profitability in retail inventory management. Strategies such as dynamic pricing, efficient inventory turnover, and optimized order quantities can bolster competitiveness. To maximize profit, retailers should factor in both constant and dynamic demand, purchase and depreciating costs, and continuous holding costs when determining selling prices. Additionally, minimizing inventory cycle time and effectively managing stock-outs through optimized order quantities are crucial for enhancing profitability.





CONCLUSION

The present research aims to develop an inventory model for linear holding costs with demand split into price-dependent and linear demand based on customer behaviour, deterioration, and continuously time-dependent demand. This model accounts for fluctuating markets, especially seasonal goods, aiming to provide optimal solutions numerically and graphically for inventory management systems. By emphasizing such as selling price, cycle length, and zero inventory periods, the study aims to maximize retailer profits through effective inventory planning. This study highlights the pivotal role of demand and procurement costs in determining selling prices, alongside factors influencing stock value such as price sensitivity, purchase cost, and holding and deterioration expenses. Cycle time is intricately tied to demand patterns, holding and deterioration costs, and holding time parameters. Demand dynamics and associated costs primarily drive order quantity, while factors like demand, backlog parameters, maintenance, and deterioration costs influence shortages. Overall profitability hinges on demand, deterioration, procurement, holding, and shortage management costs, with increased demand and optimized cost structures leading to enhanced profitability. The study underscores the importance of interpreting selling price, cycle length, and zero inventory periods to maximize retailer profit. Effective inventory planning involves managing stockout times, consumption rates, and degradation functions. The practicality of the model is enhanced through sensitivity analysis and real-world application. The proposed model incorporates realistic inventory features like electronic components, fashionable clothes, domestic goods, fruits, and fish, providing managerial implications for retailers. Future studies might expand this study to include trade credit and analyze fuzzy variables in crucial metrics like demand rate, holding cost, and ordering cost.

REFERENCES

1. T.M. Whitin (1955), Inventory control and price theory, *Management Science*, Vol. 2, pp. 61-68.
2. P.M. Ghare and G.F. Schrader (1963), A model for exponentially decaying inventory, *Journal of Industrial Engineering*, Vol. 14, pp. 238-243.
3. R.P. Covert and G.C. Philip (1973), An EOQ model for items with Weibull distribution deterioration, *AIIE Transactions*, Vol. 5, pp. 323-326.
4. W.A. Donaldson (1977), Inventory replenishment policy for a linear trend in demand-an analytical solution, *Operational Research Quarterly*, Vol. 28, No. 3, pp. 663-670.
5. B. Mondal, A.K. Bhunia and M. Maiti (2003), An inventory system of ameliorating items for price dependent demand rate, *Computers and Industrial Engineering*, Vol. 45, No. 3, pp. 443-456.
6. P.S. You (2005), Inventory policy for products with price and time dependent demand. *Journal of the Operational Research Society*, Vol. 56, pp. 870-873.
7. S.K. Ghosh and K.S. Chaudhuri (2006), An EOQ model with a quadratic demand, time-proportional deterioration and shortages in all cycles, *International Journal of systems science*, Vol. 37, No. 10, pp. 663-672, DOI:10.1080/00207720600568145.
8. B. Sarkar and S. Sarkar (2013), An improved inventory model with partial backlogging, time varying deterioration and stock-dependent demand, *Economic Modelling*, Vol. 30, pp. 924-932.
9. T. Avinadav, A. Herbon and U. Spiegel (2013), Optimal inventory policy for a perishable item with demand function sensitive to price and time, *International Journal of Production Economics*, Vol. 144, pp. 497-506.
10. V.K. Mishra (2014), Deteriorating Inventory Model with Controllable Deterioration Rate for Time-Dependent Demand and Time-Varying Holding Cost, *Yugoslav Journal of Operations Research*, No. 1, pp. 87-98, DOI: 10.2298/YJOR120823018M.
11. H.K. Alfares and A.M. Ghaithan (2016), Inventory and pricing model with price-dependent demand, time-varying holding cost, and quantity discounts, *Computers & Industrial Engineering*, Vol. 94, pp. 170-177.
12. K. Prasad and B. Mukherjee (2016), Optimal inventory model under stock and time dependent demand for time varying deterioration rate with shortages, *Annals of Operations Research*, Vol. 243, pp. 323-334.





Vanjikkodi and Pankajam

13. M.A. Hossen, M.A. Hakin, S. Sabbir, Ahmed and M.S. Uddin (2016), An Inventory Model with Price and time Dependent Demand with fuzzy valued Inventory costs under Inflation, *Annals of Pure and Applied Mathematics*, Vol.11, 2, pp.21-32.
14. S. Kumar (2016), Optimization of Deteriorating Items Inventory Model with Price and Time Dependent Demand, *Amity Journal of Operations Management*, 1(1), pp.64-76.
15. N.H. Shah, U. Chaudhari and M.Y. Jani (2017), Optimal policies for time varying deteriorating item with preservation technology under selling price and trade credit dependent quadratic demand in a supply chain, *International Journal Applied and Computational Mathematics*, Vol. 3, pp. 363-379.
16. R.P. Tripathi and S.S. Tomar (2018), Establishment of EOQ model with Quadratic time sensitive demand and parabolic time linked holding cost with salvage value, *International Journal of Operations Research*, Vol. 15, No. 3, pp.135-144, [http://doi.org/10.6886/IJOR.201809-15\(3\).0003](http://doi.org/10.6886/IJOR.201809-15(3).0003).
17. S. Singh, S. Sharma and S.R. Singh (2019), Inventory model for deteriorating items with incremental holding cost under partial backlogging, *International Journal of Mathematics in Operational Research*, Vol. 15, No. 1, pp.110-126, <https://doi.org/10.1504/IJMOR.2019.101615>.
18. S.P.S. Kornu, A.L. Rao and R.S. Kumar (2019), EOQ Model for Deteriorating Items with Time and Selling Price Dependent Demand and Time Varying Holding Cost under Partial Backlogging, *International Journal of Analytical and Experimental Modal Analysis*, Vol. XI, No. XI, pp. 2568-2577.
19. Md.A. Rahman and A.F. Uddin (2020), Analysis of inventory model with time dependent Quadratic demand function including Time variable deterioration rate without shortage, *Asian Research Journal of Mathematics*, Vol. 16, No. 12, pp.97-109, DOI: 10.9734/arjom/2020/v16i1230258.
20. M.A.A. Khan, A.A. Shaikh, I. Konstantaras, A.K. Bhunia and L.E. Cardenas-Barron (2020), Inventory models for perishable items with advanced payment, linearly time-dependent holding cost and demand dependent on advertisement and selling price, *International Journal of Production Economics*, Vol. 230, <https://doi.org/10.1016/j.ijpe.2020.107804>.
21. B. Samanta and B.C. Giri (2021), A Two-Echelon Supply Chain Model with Price and Warranty Dependent Demand and Pro-Rata Warranty Policy under Cost Sharing Contract, *Decision Making, Applications in Management and Engineering*, Vol. 4, No. 2, pp. 47-75. DOI: <https://doi.org/10.31181/dmame210402047s>.
22. A. Sayal, A.P. Singh, A. Chauhan and N. Dhiman (2022), Optimization of inventory model for deteriorating items with time varying holding cost under uncertainty, *International Conference on Advancements in Engineering and Sciences*, Vol. 2481, No. 1, <https://doi.org/10.1063/5.0103766>.
23. G. Khare and G. Sharma (2022), Effects on Inventory model in Time Deteriorate Rate with Variable cost, *International Journal of Intelligent Systems and Applications in Engineering*, Vol. 10, No. 3s, pp.45-50.
24. M.A.A. Khan, M.A. Halim, A. AlArjani, A.A. Shaikh and Md. Sharif Uddin (2022), Inventory management with hybrid cash-advance payment for time dependent demand, time varying holding cost and non-instantaneous deterioration under backordering and non-terminating situations, *Alexandria Engineering Journal*, Vol. 61, pp.8469-8486, <https://doi.org/10.1016/j.aej.2022.02.006>.
25. C.K. Sivashankari and P. Vijayakumar (2023), Effect of stock-dependent demand in EOQ models for deteriorative items under linear, quadratic and exponential holding cost, *International Journal of Procurement Management*, Vol. 17, No. 2, pp.151-179, <https://doi.org/10.1504/IJPM.2023.130747>.
26. K. Rana and S.R. Singh (2023), A sustainable production inventory model for growing items with trade credit policy under partial backlogging, *International Journal of Advanced Operations Management*, Vol. 15, No. 1, DOI.101504/IJAOM.2023.10054672.
27. M.Z. Babai, D. Ivanov and O.K. Kwon (2023), Optimal ordering quantity under stochastic time-dependent price and demand with a supply disruption: A solution based on the change of measure technique, *Omega*, Vol. 116, <https://doi.org/10.1016/j.omega.2022.102817>.
28. P. Narang and P.K. De (2023), An imperfect production-inventory model for reworked items with advertisement, time and price dependent demand for non-instantaneous deteriorating item using genetic algorithm, *International Journal of Mathematics in Operational Research*, Vol. 24, No. 1, pp 53-77, <https://doi.org/10.1504/IJMOR.2023.128645>.





Vanjikkodi and Pankajam

29. A. Kumar, A.S. Yadav and D. Yadav (2024), A Two-Storage Production Inventory Model for Deteriorating Items with Time and Selling Price Dependent Demand using Flower Pollination Optimization, *Journal of Research Administration Society of Research Administrator’s International*, Vol. 6, No. 1, pp. 2950-2966.

30. C.T. Nautiyal (2024), EOQ Model with Non-Linear Holding Costs and Hybrid Demand, *International Research Journal of Modernization in Engineering Technology and Science*, Vol. 6, No. 1, <https://www.doi.org/10.56726/IRJMETS48880>.

31. S. Shee and T. Chakrabarti (2024), An Inventory Model for Deteriorating Products with Lead Time and Selling Price Sensitive Demand under Two Level Storage Facility, *International Journal of Engineering Applied Sciences and Technology*, Vol. 8, No. 9, pp. 73-80.

APPENDIX

$$\frac{\partial Q}{\partial p} = -b \left(t_1 + \frac{\theta t_1^3}{6} + \frac{\theta^2 t_1^5}{40} \right)$$

$$\frac{\partial^2 Q}{\partial p^2} = 0$$

$$\frac{\partial Q}{\partial t_1} = (a - bp) \left(1 + \frac{\theta t_1^2}{2} + \frac{\theta^2 t_1^4}{8} \right) + c \left(t_1 + \frac{\theta t_1^3}{2} + \frac{\theta^2 t_1^5}{8} \right) - \left(\frac{a + \frac{c}{\delta} + cT}{1 + \delta(T - t_1)} \right) + \frac{c}{\delta}$$

$$\frac{\partial^2 Q}{\partial t_1^2} = (a - bp) \left(\theta t_1 + \frac{\theta^2 t_1^3}{2} \right) + c \left(t_1 + \frac{3\theta t_1^2}{2} + \frac{5\theta^2 t_1^4}{8} \right) - \left(\frac{\delta \left(a + \frac{c}{\delta} + cT \right)}{(1 + \delta(T - t_1))^2} \right)$$

$$\frac{\partial Q}{\partial T} = \left(\frac{a + \frac{c}{\delta} + cT}{1 + \delta(T - t_1)} \right) + \frac{c}{\delta} \ln(1 + \delta(T - t_1)) - \frac{c}{\delta}$$

$$\frac{\partial^2 Q}{\partial T^2} = \frac{2(1 + \delta(T - t_1)) - \delta \left(a + \frac{c}{\delta} + cT \right)}{(1 + \delta(T - t_1))^2}$$

Table 1. Sensitivity analysis for all input parameters

Parameter	Change of parameter	p	t ₁	T	S	R	TP
a	380	93.31	2.4468	4.5488	821.8993	141.6647	7873.54
	390	95.53	2.4379	4.5944	862.6854	146.4793	8578.72
	400	97.76	2.4304	4.6404	904.0953	151.3537	9313.73
	410	100.00	2.4242	4.6875	946.1016	156.2796	10078.62
	420	102.24	2.4190	4.7344	988.6793	161.2505	10873.41
b	3	130.49	2.4192	5.4334	1218.1752	146.3387	17151.79
	3.5	111.66	2.4112	4.9772	1043.5777	148.4898	12576.93
	4	97.76	2.4304	4.6408	904.0953	151.3537	9313.73
	4.5	87.16	2.4842	4.4064	790.6791	156.3325	6905.38
	5	78.90	2.5901	4.2773	698.2919	166.2266	5081.43





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c	8	96.35	2.4326	4.5614	857.7548	166.0703	9008.01
	9	97.05	2.4312	4.6003	880.6197	158.7094	9159.74
	10	97.76	2.4304	4.6408	904.0953	151.3537	9313.73
	11	98.47	2.4301	4.6824	928.2057	143.9905	9470.09
	12	99.19	2.4303	4.7252	952.9755	136.6088	9628.87
θ	0.75	97.78	2.5400	4.7773	917.0410	156.8011	9174.69
	0.80	97.77	2.4830	4.7065	910.3710	153.9665	9246.07
	0.85	97.76	2.4304	4.6408	904.0953	151.3537	9313.73
	0.90	97.75	2.3816	4.5795	898.1708	148.9331	9378.07
	0.95	97.74	2.3362	4.5223	892.5609	146.6807	9439.39
δ	0.04	98.19	2.4767	4.7848	963.6021	151.0587	9520.23
	0.05	97.97	2.4531	4.7112	932.8452	151.2222	9414.57
	0.06	97.76	2.4304	4.6408	904.0953	151.3537	9313.73
	0.07	97.55	2.4086	4.5734	877.1532	151.4575	9217.35
	0.08	97.35	2.3876	4.5089	851.8460	151.5372	9125.08
k	35	96.99	2.3700	4.6615	934.8519	155.7557	10467.46
	37.5	97.37	2.3994	4.6510	919.7331	153.5767	9886.52
	40	97.76	2.4304	4.6408	904.0953	151.3537	9313.73
	42.5	98.15	2.4633	4.6311	887.9292	149.0886	8749.50
	45	98.55	2.4983	4.6222	871.2268	146.7846	8194.25
d	16	97.57	2.3594	4.5419	891.6180	140.6533	9396.31
	18	97.66	2.3938	4.5898	897.6612	145.7523	9355.91
	20	97.76	2.4304	4.6408	904.0953	151.3537	9313.73
	22	97.87	2.4695	4.6952	910.9687	157.5364	9269.62
	24	97.99	2.5116	4.7537	918.3383	164.3961	9223.37
s	13	98.55	2.5200	5.0205	1020.4603	151.4459	9766.97
	14	98.15	2.4738	4.8208	958.9703	151.4534	9531.18
	15	97.76	2.4304	4.6408	904.0953	151.3537	9313.73
	16	97.38	2.3895	4.4775	854.8104	151.1744	9112.48
	17	97.02	2.3508	4.3285	810.2955	150.9359	8925.59
l	11	97.85	2.4406	4.6823	916.7207	151.3858	9364.37
	13	97.81	2.4355	4.6614	910.3671	151.3703	9338.93
	15	97.76	2.4304	4.6408	904.0953	151.3537	9313.73
	17	97.71	2.4254	4.6203	897.9038	151.3359	9288.77
	19	97.67	2.4204	4.6001	891.7910	151.3171	9264.03
α	1.1	97.71	2.4158	4.6199	901.3314	149.2943	9330.31
	1.3	97.74	2.4231	4.6303	902.7074	150.3133	9322.06
	1.5	97.76	2.4304	4.6408	904.0953	151.3537	9313.73
	1.7	97.78	2.4378	4.6513	905.4955	152.4163	9305.35
	1.9	97.81	2.4453	4.6620	906.9082	153.5018	9296.90
β	0.08	97.76	2.4298	4.6400	904.0166	151.2413	9314.38
	0.09	97.76	2.4301	4.6404	904.0559	151.2975	9314.06
	0.10	97.76	2.4304	4.6408	904.0953	151.3537	9313.73
	0.11	97.76	2.4307	4.6411	904.1347	151.4100	9313.41
	0.12	97.76	2.4310	4.6415	904.1741	151.4664	9313.09





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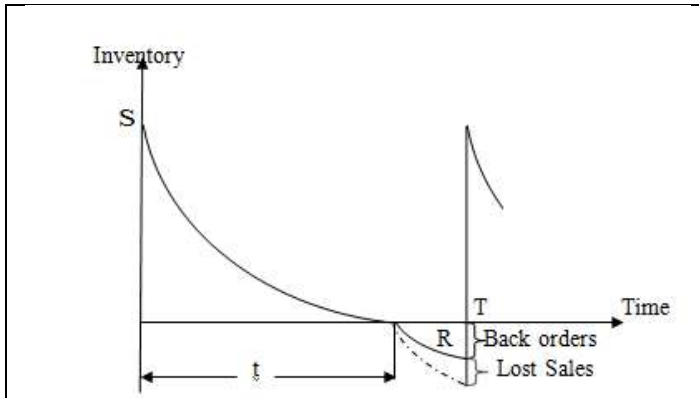
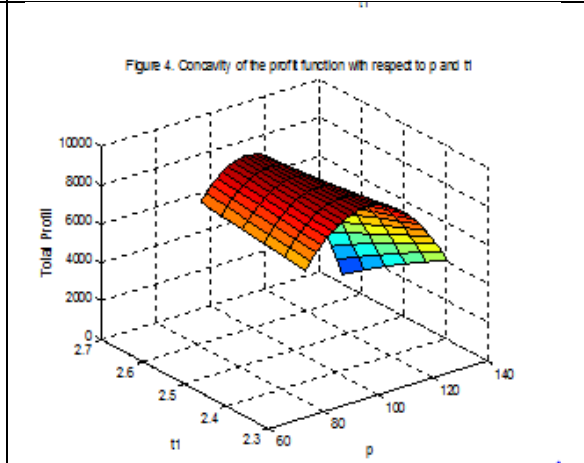
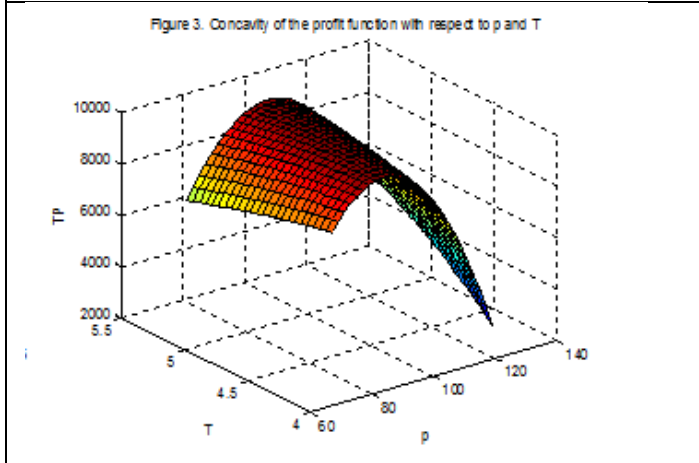
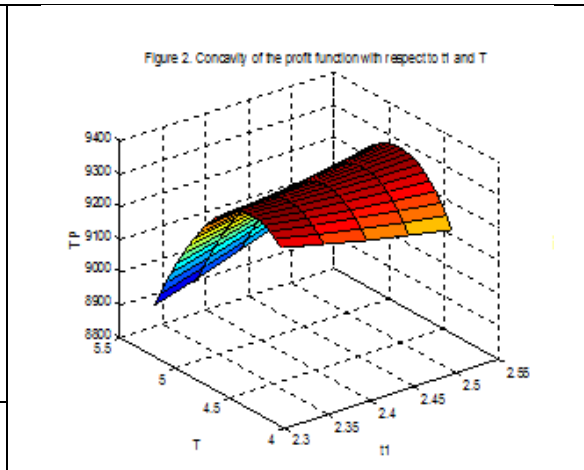


Figure 1. The proposed model is visually presented, highlighting partial backlog shortages





Low Level of Ambulatory Physical Activity is a Risk Factor for Persisting Pain in Acute / Subacute Low Back Pain – A Prospective Cohort Study

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ABSTRACT

Low back pain (LBP) is a common musculoskeletal condition that can significantly impact individuals' quality of life. Acute and subacute LBP are phases of the condition that often transition into chronic pain, leading to prolonged suffering and increased healthcare utilization. Ambulatory physical activity has been proposed as a potential modifiable factor in the progression of LBP. Fear avoidance beliefs and the active endurance theory provide contrasting explanations for the relationship between physical activity and pain persistence. This study aims to explore whether a low level of ambulatory physical activity is a risk factor for the persistence of pain in acute and subacute LBP patients. The specific objective of this prospective cohort study is to determine whether low levels of ambulatory physical activity in patients with acute and subacute LBP are associated with an increased risk of pain persistence after a 3-month follow-up period. This prospective cohort study examined ambulatory activity's link to pain persistence in acute/subacute LBP. Conducted among Surat district community patients (Oct 2018 - Mar 2021), participants aged 18-65 with acute/subacute LBP were included, excluding severe impairments, LBP-causing conditions, malignancy, and regular exercise participants. Activity levels were categorized into low / very low and moderate/high level physical activity by ActiGraph GT3XP accelerometer. Pain persistence was assessed using Numeric Pain Rating Scale (NPRS) after 3 months. Logistic regression, adjusting for confounders, evaluated physical activity's pain persistence association. Sensitivity analyses tested the result robustness. The study involved 31 participants with acute or subacute LBP (14 acute, 17 subacute). Participants' average age was 39.69 ± 7.2 years, with 13 males and 18 females. Baseline pain scores (NPRS) averaged 5.56 ± 1.13 ; the average ODI score was 37.4 ± 6.1 . 20 participants were in the



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low/very low activity group, while 11 were in the moderate/high activity group. After 3 months, 14 low/very low activity participants had pain persistence, contrasting with 4 without. Similarly, 3 moderate/high activity participants experienced pain persistence, with 8 without. Low/very low activity participants (64.5%) had significantly higher pain persistence risk (adjusted OR: 8.67, 95% CI: 2.87-39.11). Sensitivity analyses consistently affirmed this association's stability. The study findings emphasize a significant relationship between low ambulatory physical activity levels and pain persistence in acute and subacute LBP patients. This aligns with the fear avoidance beliefs model, highlighting the importance of addressing avoidance behavior to prevent pain chronicity. The active endurance theory also supports these findings, suggesting that engaging in suitable physical activities can inhibit pain and enhance tissue healing. The study contributes crucial insights into the role of ambulatory physical activity in pain persistence among patients with acute and subacute LBP. Healthcare professionals should consider physical activity levels in clinical management, devising tailored interventions to promote appropriate activity and address fear avoidance beliefs. These efforts could potentially reduce pain persistence, enhance functional capacity, and alleviate the burden on healthcare resources. Future research should explore interventions and larger cohorts to validate these findings and optimize management strategies.

Keywords: Low back pain, Ambulatory physical activity, Pain persistence, Acute and subacute LBP, Fear avoidance beliefs, Prospective cohort study

INTRODUCTION

Low back pain (LBP) is a prevalent and debilitating musculoskeletal condition that affects individuals of all ages, causing substantial pain, disability, and socioeconomic burden worldwide (1). It is estimated that up to 80% of individuals will experience LBP at some point in their lives, leading to considerable healthcare costs and reduced quality of life (2). LBP is a complex and heterogeneous condition with a spectrum of clinical presentations, ranging from acute, sudden-onset pain to chronic, persistent discomfort. LBP can be categorized into various phases based on the duration of symptoms, with acute LBP lasting up to six weeks and subacute LBP extending from six weeks to three months (3). While acute and subacute LBP often resolve without medical intervention, a significant proportion of cases progress to chronic LBP, characterized by pain persisting beyond three months, leading to prolonged suffering, diminished functional capacity, and an increased burden on healthcare resources (4). The transition from acute or subacute LBP to chronicity is a critical juncture that has garnered substantial attention in clinical and research realms. It is during this transition that factors contributing to pain persistence and the maintenance of disability may exert their influence, potentially shaping the trajectory of the condition (5). One such factor that has gained increasing recognition is ambulatory physical activity, encompassing daily movements such as walking, standing, and other moderate-intensity activities, which has gained recognition as a potential factor influencing the course of LBP (6). The role of physical activity in musculoskeletal health has been extensively studied, and evidence suggests that appropriate levels of activity can contribute to pain relief, functional improvement, and prevention of disability (7,8). However, the relationship between ambulatory physical activity and the persistence of pain in individuals with acute and subacute LBP remains an area of active investigation. Fear avoidance beliefs and the active endurance theory provide contrasting explanations for the potential influence of physical activity on LBP outcomes (9). Fear avoidance beliefs postulate that individuals with LBP may avoid physical activity due to apprehension of pain exacerbation, which may contribute to deconditioning and further pain persistence (10). This avoidance-based approach is thought to contribute to increased disability and a heightened risk of transitioning to chronic LBP (11). In contrast, the active endurance theory suggests that engaging in appropriate levels of physical activity may promote the development of pain-inhibitory mechanisms, reduce inflammation, and enhance tissue healing, ultimately leading to a decrease in pain persistence (12). Empirical evidence supporting the potential impact of ambulatory physical activity on LBP outcomes is emerging (13). A study by Smith et al. found that individuals



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with chronic LBP who engaged in regular physical activity demonstrated improved pain and disability scores compared to sedentary counterparts (14). Similarly, a recent systematic review and meta-analysis by Gordon et al. indicated that higher levels of physical activity were associated with reduced risk of developing chronic LBP (15). However, the existing literature predominantly focuses on chronic LBP populations, with limited exploration of the role of physical activity in the transition from acute and subacute phases to chronicity. This study aims to address this gap by investigating whether a low level of ambulatory physical activity is a risk factor for the persistence of pain in patients with acute and subacute LBP. By prospectively evaluating the relationship between ambulatory physical activity levels and pain outcomes over a three-month follow-up period, we seek to contribute to a better understanding of the potential mechanisms underlying pain chronicity in early phases of LBP. Furthermore, this study aims to provide valuable insights into the clinical management of acute and subacute LBP, offering potential avenues for interventions that may prevent or mitigate the transition to chronicity. In summary, the current understanding of the relationship between ambulatory physical activity and pain outcomes in acute and subacute LBP is limited, and existing research primarily focuses on chronic LBP populations. This study will address this gap by prospectively investigating the role of ambulatory physical activity in the persistence of pain in patients with acute and subacute LBP, contributing to a more comprehensive understanding of pain progression and potential avenues for targeted interventions.

Objectives

The specific objective of this prospective cohort study is to determine whether low levels of ambulatory physical activity in patients with acute and subacute LBP are associated with an increased risk of pain persistence after a 3-month follow-up period.

METHODS**Study Design**

This prospective cohort study aimed to investigate the association between ambulatory physical activity levels and the persistence of pain in patients with acute and subacute low back pain (LBP). The study design adhered to the STROBE cohort guidelines (16).

Setting and Participants

The study was conducted in the Surat district of Gujarat, India, between October 2018 and March 2021. Community-based participants were recruited through local healthcare facilities and community centers using a convenience sampling method. Inclusion criteria encompassed individuals aged 18 to 65 years with a diagnosis of acute or subacute LBP, defined as pain lasting up to three months. Participants were excluded if they presented with severe physical impairment precluding ambulatory physical exercise (e.g., bilateral amputation, complete blindness), had medical conditions known to cause LBP or malignancy, or were participating in regular exercise programs.

Ethical Considerations

Institutional ethical approval was obtained from the Institutional Ethical Committee before the commencement of the study (Ethics approval number). All participants provided informed consent before participating in the study, and confidentiality of their personal and medical information was ensured throughout the research process.

Exposure Assessment

Ambulatory physical activity was objectively assessed using the ActiGraph GT3XP accelerometer (ActiGraph, Pensacola, FL, USA), a reliable and validated device for objective physical activity measurement (17). Participants were instructed to wear the accelerometer on the wrist for three consecutive days, removing it only during water-based activities (e.g., swimming, bathing). The accelerometer recorded triaxial acceleration data in 5-second epochs. The raw acceleration data were processed using ActiLife software (version 6.13.3, ActiGraph, Pensacola, FL, USA) to calculate activity counts. Physical activity levels were categorized into four distinct levels based on the duration of



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engagement in various activities: high-level activities (>8,000 units/5 minutes; e.g., running, gardening), moderate-level activities (>3,000–8,000 units/5 minutes; e.g., effortful walking), low-level activities (1,000–3,000 units/5 minutes; e.g., office work, minimal physical activity), and very low activity levels (<1,000 units/5 minutes; e.g., sitting still, lying down). The percentage of time spent in high-level activities was used as an additional measure to avoid potential biases resulting from chance observations resulting from a single 5-minute period (18).

Baseline Data Collection

Demographic information, including age and gender, was collected at baseline. Pain intensity was assessed using the Numeric Pain Rating Scale (NPRS), a validated self-report measure for pain assessment (19). Participants also completed the Oswestry Disability Index (ODI), a questionnaire evaluating self-perceived functional disability related to LBP (20).

Group Allocation

Participants were categorized into two groups based on their ambulatory physical activity levels. The low/very low activity group included participants spending a higher proportion of time in low and very low activity levels, while the moderate/high activity group consisted of those engaged in moderate and high levels of physical activity.

Follow-up and Outcome Assessment

Follow-up assessments were conducted three months after baseline evaluation. Pain persistence was the primary outcome, defined as a Numeric Pain Rating Scale score ≥ 4 at the three-month follow-up (21). Participants' pain intensity were re-evaluated using the NPRS and ODI, respectively.

DATA ANALYSIS

Data were analyzed using SPSS Statistics (version 22.0, IBM Corp.). Descriptive statistics, including means, standard deviations, frequencies, and percentages, were computed for participant characteristics and baseline measurements. Differences between the low/very low and moderate/high activity groups were assessed using independent t-tests for continuous variables and chi-square tests for categorical variables. To explore the association between ambulatory physical activity levels and pain persistence, unadjusted and adjusted logistic regression analyses were performed. The unadjusted model examined the relationship between ambulatory physical activity levels and pain persistence, without accounting for potential confounding factors. The adjusted model included potential confounders identified a priori, such as age, gender, baseline pain intensity, and baseline disability. Odds ratios (ORs) and 95% confidence intervals (CIs) were calculated for both unadjusted and adjusted models. Sensitivity analyses were performed to assess the robustness of the findings. These analyses involved varying the inclusion/exclusion criteria for participants or adjusting for different sets of confounding variables. The purpose of sensitivity analyses was to evaluate the stability of the observed association between ambulatory physical activity levels and pain persistence.

No missing data were identified for the variables of interest in this study. Statistical significance was set at $p < 0.05$ for all analyses.

RESULTS**Participant Characteristics**

A total of 31 participants were included in the study, with 14 individuals categorized as having acute LBP and 17 with subacute LBP. The mean age of the participants was 39.69 years (± 7.2), with 13 males and 18 females. At baseline, the mean Numeric Pain Rating Scale (NPRS) score was 5.56 (± 1.13), and the mean Oswestry Disability Index (ODI) score was 37.4 (± 6.1). Among the participants, 20 were classified as engaging in low or very low levels of physical activity, while 11 participants exhibited moderate or high levels of physical activity. Table 1 presents the



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sociodemographic characteristics of the study participants at baseline, including age, gender distribution, and ambulatory physical activity group.

Outcome Assessment

At the three-month follow-up assessment, participants were evaluated for pain persistence using the NPRS. Among those in the low/very low activity group, 14 individuals reported persistent pain, while 6 participants did not experience pain persistence. In contrast, among the moderate/high activity group, 3 participants reported persistent pain, while 8 did not. Table 2 summarizes the distribution of pain persistence by ambulatory physical activity group

Unadjusted and Adjusted Logistic Regression Analysis

The association between ambulatory physical activity levels and pain persistence was investigated using logistic regression analysis. In the unadjusted model, participants in the low/very low activity group were found to have an odds ratio (OR) of 9.3 (95% confidence interval [CI]: 2.200-39.329) for pain persistence compared to those in the moderate/high activity group. After adjusting for potential confounders, including age, gender, baseline pain intensity, and baseline disability, the association remained significant. In the adjusted model, participants in the low/very low activity group had an OR of 8.67 (95% CI: 2.87-39.11) for pain persistence compared to the moderate/high activity group. Table 2 presents the results of the unadjusted and adjusted logistic regression analyses, providing odds ratios and 95% confidence intervals.

Sensitivity Analysis

Sensitivity analyses were conducted to assess the robustness of the observed association between ambulatory physical activity levels and pain persistence. Various scenarios were explored, including different inclusion/exclusion criteria and adjustments for different sets of confounding variables. Across these sensitivity analyses, the consistent trend of a higher odds ratio for pain persistence in the low/very low activity group was observed, albeit with varying magnitudes.

DISCUSSION

The study findings suggest a significant association between ambulatory physical activity levels and the persistence of pain in patients with acute and subacute low back pain (LBP). The analysis revealed that participants in the low/very low activity group had a substantially higher risk of pain persistence after a three-month follow-up period compared to those in the moderate/high activity group. This association remained robust even after adjusting for potential confounding factors such as age, gender, baseline pain intensity, and baseline disability. The observed association between low ambulatory physical activity levels and pain persistence aligns with the fear avoidance beliefs model, which suggests that individuals with LBP may avoid physical activity due to the fear of pain exacerbation (22). This avoidance behavior can lead to deconditioning and contribute to the maintenance of pain and disability (10). The present study's findings reinforce the importance of addressing fear avoidance beliefs in clinical practice and promoting gradual engagement in physical activities that are appropriate for individuals with acute and subacute LBP (11). These results align with previous research that has highlighted the potential influence of physical activity on pain outcomes in musculoskeletal conditions (14,15). The higher odds of pain persistence among individuals with low/very low ambulatory activity levels emphasize the importance of maintaining an appropriate level of physical activity in the early phases of LBP (23). The active endurance theory, which suggests that engaging in physical activity can promote pain inhibition and tissue healing, may provide insights into the mechanisms underlying this association (12). These results are consistent with prior research that has demonstrated the positive impact of physical activity on pain outcomes. A study by Smith et al. showed that individuals with chronic LBP who engaged in regular physical activity demonstrated improved pain and disability scores compared to sedentary counterparts (14). Similarly, a systematic review and meta-analysis by Gordon et al. indicated that higher levels of physical activity were associated with a reduced risk of developing chronic LBP (15). While these studies focused on chronic LBP populations, the current study extends the evidence base by examining the potential role of physical



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activity in the transition from acute and subacute LBP to chronicity. The findings have important clinical implications. Healthcare professionals managing patients with acute and subacute LBP should consider the role of ambulatory physical activity in the progression of pain and incorporate assessment of physical activity and tailored recommendations into their practice (23). Encouraging patients to engage in appropriate levels of physical activity, while addressing fear avoidance beliefs, could potentially contribute to a reduction in pain persistence and disability (24). Tailored interventions aimed at promoting physical activity in individuals with LBP could be developed to mitigate the risk of transitioning to chronic pain, thereby improving patients' overall quality of life (25). Strengths of this study include its prospective cohort design and adherence to the STROBE guidelines, which enhance the methodological rigor and validity of the findings (16). The utilization of objective measures of physical activity and validated pain assessment tools further strengthens the reliability of the results (17,18). The sensitivity analyses conducted to assess the robustness of the observed association add to the credibility of the findings and support the consistency of the trend (19). While the study contributes valuable insights into the role of ambulatory physical activity in the early phases of LBP, certain limitations should be acknowledged.

The study was conducted in a specific geographical location, and the generalizability of the findings to diverse populations requires further exploration (26). Additionally, while efforts were made to control for potential confounding factors through adjustment in the regression models, the presence of unmeasured or residual confounding cannot be entirely ruled out (27). Moreover, the study's follow-up period was limited to three months, and longer-term observations are necessary to capture the full trajectory of pain persistence (28). Future research endeavors could expand on these findings by incorporating larger and more diverse cohorts to enhance external validity (23). Longitudinal studies with extended follow-up periods would provide a more comprehensive understanding of the relationship between physical activity and pain persistence (29). Moreover, assessing the impact of different types of interventions aimed at promoting physical activity on pain outcomes could further elucidate the causal pathways and mechanisms involved (28). In conclusion, this prospective cohort study sheds light on the crucial role of ambulatory physical activity in the persistence of pain among patients with acute and subacute LBP. The significant association between low/very low activity levels and pain persistence underscores the need for interventions that promote appropriate physical activity to prevent the transition to chronic pain (24). By considering the active endurance theory and fear avoidance beliefs, healthcare providers can devise strategies to empower individuals with LBP to engage in beneficial physical activities. Ultimately, these efforts may lead to improved pain management, enhanced functional capacity, and a reduced burden on healthcare resources.

CONCLUSION

This prospective cohort study provides preliminary evidence that low levels of ambulatory physical activity may contribute to the persistence of pain in patients with acute and subacute LBP. These findings underscore the importance of promoting physical activity in the management of LBP and highlight the need for further research in this area.

REFERENCES

1. Hoy D, Brooks P, Blyth F, Buchbinder R. The Epidemiology of low back pain. *Best Pract Res Clin Rheumatol.* 2010 Dec 1;24(6):769–81.
2. Hartvigsen J, Hancock MJ, Kongsted A, Louw Q, Ferreira ML, Genevay S, et al. What low back pain is and why we need to pay attention. *Lancet Lond Engl.* 2018 Jun 9;391(10137):2356–67.
3. Balagué F, Mannion AF, Pellisé F, Cedraschi C. Non-specific low back pain. *Lancet Lond Engl.* 2012 Feb 4;379(9814):482–91.



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4. Henschke N, Maher CG, Refshauge KM, Herbert RD, Cumming RG, Bleasel J, et al. Prevalence of and screening for serious spinal pathology in patients presenting to primary care settings with acute low back pain. *Arthritis Rheum.* 2009 Oct;60(10):3072–80.
5. Henschke N, Kamper SJ, Maher CG. The epidemiology and economic consequences of pain. *Mayo Clin Proc.* 2015 Jan;90(1):139–47.
6. Hildebrandt VH, Bongers PM, Dul J, van Dijk FJ, Kemper HC. The relationship between leisure time, physical activities and musculoskeletal symptoms and disability in worker populations. *Int Arch Occup Environ Health.* 2000 Nov;73(8):507–18.
7. Hurwitz EL, Morgenstern H, Chiao C. Effects of recreational physical activity and back exercises on low back pain and psychological distress: findings from the UCLA Low Back Pain Study. *Am J Public Health.* 2005 Oct;95(10):1817–24.
8. O'Halloran PD, Blackstock F, Shields N, Holland A, Iles R, Kingsley M, et al. Motivational interviewing to increase physical activity in people with chronic health conditions: a systematic review and meta-analysis. *Clin Rehabil.* 2014 Dec;28(12):1159–71.
9. Heneweer H, Vanhees L, Picavet HSJ. Physical activity and low back pain: a U-shaped relation? *Pain.* 2009 May;143(1–2):21–5.
10. Fear-avoidance and its consequences in chronic musculoskeletal pain: a state of the art - PubMed [Internet]. [cited 2023 Aug 21]. Available from: <https://pubmed.ncbi.nlm.nih.gov/10781906/>
11. Leeuw M, Goossens MEJB, Linton SJ, Crombez G, Boersma K, Vlaeyen JWS. The fear-avoidance model of musculoskeletal pain: current state of scientific evidence. *J Behav Med.* 2007 Feb;30(1):77–94.
12. Mannion AF, Käser L, Weber E, Rhyner A, Dvorak J, Müntener M. Influence of age and duration of symptoms on fibre type distribution and size of the back muscles in chronic low back pain patients. *Eur Spine J.* 2000 Aug;9(4):273–81.
13. Hayden JA, van Tulder MW, Malmivaara AV, Koes BW. Meta-analysis: exercise therapy for nonspecific low back pain. *Ann Intern Med.* 2005 May 3;142(9):765–75.
14. Smith BE, Littlewood C, May S. An update of stabilisation exercises for low back pain: a systematic review with meta-analysis. *BMC Musculoskelet Disord.* 2014 Dec 9;15(1):416.
15. Gordon R, Bloxham S. A Systematic Review of the Effects of Exercise and Physical Activity on Non-Specific Chronic Low Back Pain. *Healthcare.* 2016 Apr 25;4(2):22.
16. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies - PubMed [Internet]. [cited 2023 Aug 21]. Available from: <https://pubmed.ncbi.nlm.nih.gov/18064739/>
17. Troiano RP, Berrigan D, Dodd KW, Mâsse LC, Tilert T, McDowell M. Physical activity in the United States measured by accelerometer. *Med Sci Sports Exerc.* 2008 Jan;40(1):181–8.
18. Limits to the measurement of habitual physical activity by questionnaires | British Journal of Sports Medicine [Internet]. [cited 2023 Aug 21]. Available from: <https://bjsm.bmj.com/content/37/3/197>
19. Farrar JT, Young JP, LaMoreaux L, Werth JL, Poole MR. Clinical importance of changes in chronic pain intensity measured on an 11-point numerical pain rating scale. *Pain.* 2001 Nov;94(2):149–58.
20. Fairbank JC, Couper J, Davies JB, O'Brien JP. The Oswestry low back pain disability questionnaire. *Physiotherapy.* 1980 Aug;66(8):271–3.
21. Health status measures: strategies and analytic methods for assessing change scores - PubMed [Internet]. [cited 2023 Aug 21]. Available from: <https://pubmed.ncbi.nlm.nih.gov/8863764/>
22. Pain-related fear in low back pain: a prospective study in the general population - PubMed [Internet]. [cited 2023 Aug 22]. Available from: <https://pubmed.ncbi.nlm.nih.gov/16546425/>
23. Shiri R, Coggon D, Falah-Hassani K. Exercise for the Prevention of Low Back Pain: Systematic Review and Meta-Analysis of Controlled Trials. *Am J Epidemiol.* 2018 May 1;187(5):1093–101.
24. Linton SJ. A review of psychological risk factors in back and neck pain. *Spine.* 2000 May 1;25(9):1148–56.
25. Panjabi MM. The stabilizing system of the spine. Part I. Function, dysfunction, adaptation, and enhancement. *J Spinal Disord.* 1992 Dec;5(4):383–9; discussion 397.





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26. Hill JC, Fritz JM. Psychosocial influences on low back pain, disability, and response to treatment. *Phys Ther.* 2011 May;91(5):712–21.
27. Years lived with disability (YLDs) for 1160 sequelae of 289 diseases and injuries 1990-2010: a systematic analysis for the Global Burden of Disease Study 2010 - PubMed [Internet]. [cited 2023 Aug 1]. Available from: <https://pubmed.ncbi.nlm.nih.gov/23245607/>
28. Abdel Shaheed C, Maher CG, Williams KA, McLachlan AJ. Efficacy and tolerability of muscle relaxants for low back pain: Systematic review and meta-analysis. *Eur J Pain Lond Engl.* 2017 Feb;21(2):228–37.
29. George SZ, Childs JD, Teyhen DS, Wu SS, Wright AC, Dugan JL, et al. Rationale, design, and protocol for the prevention of low back pain in the military (POLM) trial (NCT00373009). *BMC Musculoskelet Disord.* 2007 Sep 14;8:92.

Table 1: Sociodemographic Characteristics of Participants at Baseline

Characteristic	Acute LBP (n=14)	Subacute LBP (n=17)	Total (n=31)
Age (years, mean ± SD)	37.8 ± 6.3	40.1 ± 7.6	39.7 ± 7.2
Gender			
- Male	7 (50.0%)	6 (35.3%)	13 (41.9%)
- Female	7 (50.0%)	11 (64.7%)	18 (58.1%)
Ambulatory Activity			
- Low/Very Low	10 (71.4%)	10 (58.8%)	20 (64.5%)
- Moderate/High	4 (28.6%)	7 (41.2%)	11 (35.5%)
NPRS (mean ± SD)			5.56 ± 1.13
ODI			37.4 ± 6.13

Table 2: Unadjusted and Adjusted Odds Ratios by Ambulatory Physical Activity Group after 3 months follow up

Physical Activity Group	Pain Persistence (Yes)	Pain Persistence (No)	Unadjusted OR	p-value (Unadjusted)	Adjusted OR	p-value (Adjusted)
Low/Very Low Activity Group	14	6	9.3333	<0.001	8.667	<0.001
High/Moderate Activity Group	3	8	0.2143	0.047	0.2454	0.056





Screening of Phytochemicals and (H₂O₂-Free Radical Scavenging Activity in *Terminalia arjuna* (Roxb.) Wight & Ar. Leaf Extract

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ABSTRACT

The plant *Terminalia arjuna* bark decoction traditionally claimed to be useful in treatment for anginal discomfort, hypertension, congestive heart failure, and dyslipidemia on the Indian subcontinent. The aim of the present study was to identify and quantify the phytoconstituents using standard biochemical test method. FTIR also used to identify functional group of secondary metabolites in powder of plant leaf. Antioxidant activity of the extract was determined by employing in vitro assays such as hydrogen peroxide using UV-Vis Spectrophotometry. The phytochemical were identified and quantified in different solvent extract. Leaves extracts showed the presence of flavonoids, phenolics, tannins, and alkaloids, phytosterols. Chloroform extract of *T. arjuna* showed high amount of phenolic and flavonoid, Phytosterols content than the other solvent extracts. Total phenolic content rate 43.80.66 µg/mg, total flavonoid content rate 49.66 µg/mg and free Phytosterols content rate 11.2 µg/mg were estimated in extracts of chloroform. FTIR results showed the presence of functional group such as hydroxyl group (O-H); aldehyde (C-H), alkenes (C=C), carboxyl (C=O); nitrogen-containing group (N-O), alkanes (C-C); amines (N-H), alkynes (C≡C). H₂O₂ free Radical Scavenging activity was further analyzed in different concentration of plant extract. The H₂O₂ scavenging activity of extract increases in a concentration-dependent manner and showed significant value (p < 0.05). This study conclude That leaf extract's capacity to scavenge free radicals may be attributed to an increased phenolic and flavonoid content.





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Keywords: Phytochemical, Phytosterols, functional group, Antioxidant

INTRODUCTION

Medicinal herbs were employed in ancient India to treat and prevent a wide range of serious illnesses. Herbal medicines can be obtained largely from the kingdom of plants. Even in recent times, people have become more conscious of the value of medicinal herbs. Herbal medications are typically readily accessible, secure, affordable, effective, and rarely have negative side effects. The World Health Organization states that the greatest place to find a wide range of medications is from medicinal plants (1). Medicinal plants contain bioactive substances include tannins, alkaloids, carbohydrates, terpenoids, steroids, flavonoids and phenols. These active phytochemical constituents with high antioxidant property play an important role in the prevention of various degenerative diseases and have possible benefits to the human. The natural products such as plant extracts provide unlimited opportunities for new drug discoveries (2). *Terminalia arjuna* (Roxb.) Wight and Arn., commonly known as "Arjuna," is an indigenous medicinal plant to India that has been used as a cardiogenic in heart failure, ischemic, cardiomyopathy, atherosclerosis, and myocardium necrosis. It has also been used to treat a variety of human diseases, including blood disorders, anaemia, venereal and viral diseases, and to maintain excellent health. It has been shown to have hypocholesterolemic, antibacterial, antimicrobial, antitumoral, antioxidant, antiallergic and antifertility, and anti-HIV properties. It is used to treat fractures, ulcers, and hepatic disorders. It has been claimed that *T. arjuna* has potent hydrophilic characteristics. It is believed that *T. arjuna*'s inotropic effects may be caused by its saponin glycosides(3). The common name of this plant is Arjun and Its botanical name is *Terminalia arjuna*. Every part of the tree has useful medicinal properties. Arjun holds a reputed position in both Ayurvedic and Yunani Systems of medicine(4). There is lack of adequate literature on the phytochemical profile and its pharmacological activity in the leaf *Terminalia arjuna*. This present study was carried out to evaluate phytochemical screening, quantitative analysis of phytochemical in *Terminalia arjuna* leaf

MATERIALS AND METHOD

Plant Collection and Extraction

Leaves *T.arjuna* were obtained in Melaneelithanallur, Sankarankoil, Tenkasi District, Tamil Nadu. Leaves are collected and dried in shade 2 weeks. Subsequently, it was ground into a fine powder and kept at 4°C in an airtight glass container shielded from the sun. Using a Soxhlet extractor at a ratio of 1:10 (w/v), the plant leaves were extracted in aqueous and 70% ethanol. Rotary evaporation was applied to the extract the liquid in clear solution. The resulting semisolid extract was kept for future use in a freezer at 4°C in an airtight container.

Phytochemical analysis of the test sample

The assessment of the chemical components found in the crude extract and the determination of which compounds are soluble in a given solvent can both be accomplished with the use of phytochemical analysis. Plants get their therapeutic properties from the presence of specific phytochemical constituents.

Salkowski reaction test for phytosterols

Added 1 mL of concentrated (conc.) H₂SO₄ from the test tube's sidewalls to 0.5 mL of chloroform extract in the tube. The presence of phytosterols is indicated by the reddish brown hue that appears in the chloroform layer^(5,6).

Steroids Liebermann-Burckhardt test:

Added 1 ml of chloroform, 2-3 ml of acetic anhydride, and 1-2 drops of concentrated H₂ SO₄ to 1 ml of sample. A dark green or reddish brown chloroform coating will be indicate positive of Steroids^(5,6).



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A few drops of acetic anhydride were added to the extract, boiling it, then cooling it. Conc. sulfuric acid was added from the test tube's sides, revealing a brown ring where two layers met and forming a deep red colour that suggested the existence of triterpenoids (5,6).

Foam test for Saponins

The foam test for the presence of Saponins was performed as described elsewhere (5,6). Briefly, A small amount of extract was added in a test tube with a small amount of water, and it was shaken hard. Presence of saponins was detected by the appearance of foam that persisting for ten minutes

Dragendroff's test for alkaloids

The plant extracts were dissolved in chloroform. After evaporating the chloroform, a small amount of Dragendroff's reagent (potassium bismuth iodide) was added to the residue to acidify it. Alkaloids were present as evidenced by the orange-red precipitate's appearance(5,6).

Molisch's test for carbohydrates

After combining the extract with the Molisch reagent, conc. H₂SO₄ was added to the test tube's sidewalls to create layers. The presence of carbohydrates was suggested by the appearance of a reddish violet ring in the interference(5,6).

Lead acetate test for flavanoids

Added a few drops of a 10% lead acetate solution to the extract's alcoholic solution. The presence of flavonoids was suggested by the yellow precipitate's appearance(5,6).

Legal's test for lactones

Added pyridine and sodium nitroprusside to the extract mixes. Following that, NaOH was applied to the mixture. The presence of lactones was suggested by the rich red colour(5,6).

Ferric chloride test for phenolic compounds and tannins

Transfer 2 ml of extract into a test tube and gradually add drops of ferric chloride solution. The presence of tannins and phenolic chemicals was suggested by the precipitate's bluish-black appearance(5,6).

Ninhydrin test for proteins

The Ninhydrin test(5,6), to verify the presence of protein was utilized. Briefly, A few ninhydrin drops were added to the extract. The presence of amino acids was indicated by the appearance of blue colour, whereas proteins may infrequently produce favourable results.

Keller-Killiani test for glycosides

The Keller-Killiani method (5,6) was used to test the presence of glycosides. Briefly, the extract was mixed with 1 mL of glacial acetic acid, a few drops of ferric chloride solution, and concentrated H₂SO₄ (slowly through the test tube's walls). The presence of deoxy sugars was suggested by the appearance of a reddish brown ring at the liquid-liquid junction.

Total phenolic content of crude extracts of Terminalia arjuna tree bark and leaves

The total phenolic content of crude extracts was determined by Folin- Ciocalteu reagent method . 0.5 mL (from 1mg/mL stock) of different solvent extracts and different concentrations (200, 400, 600, 800 and 1000 µg/mL) of standard gallic acid were taken and made up to 2 mL using double distilled water. Added 1 mL of 10% Na₂CO₃ and 1 mL of Folin- Ciocalteu reagent (1:10 dilution in distilled water) and incubated for 2 h at room temperature. The



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absorbance was read at 760 nm against Folin- Ciocalteu reagent as a blank. The amount of phenolic content was determined by gallic acid standard curve(7).

Total flavonoid content of crude extracts of Terminalia arjuna tree bark and leaves

The total flavonoid content of the plant extracts was measured using the $AlCl_3$ technique. The total flavonoid content of crude extracts was determined by colorimetric method (Rajurkar *et al.*, 2011). Different concentrations of standard quercetin (200, 400, 600, 800 and 1000 $\mu\text{g/mL}$) and 0.5 mL of (from 1mg/mL stock) different solvent extracts were taken and made up to 2 mL using distilled water and consequently added 0.15 mL of $NaNO_2$ solution and allowed to stand for 6 min. To this 0.15 mL of 10% $AlCl_3$ in methanol was added and allowed to stand for 6 min at room temperature. After that 2 mL of 4% $NaOH$ solution was added immediately followed by adding distilled water to make up the volume upto 5 mL and incubated for 15 min at room temperature. The absorbance of the content was read at 510 nm against blank. The amount of flavonoid content was determined from quercetin standard curve. (7)

Estimation of Free Phytosterols by UV-Vis Spectrometry, (Liebermann-Burchard test) in Extraction of Terminalia arjuna leaves

For the ethanolic extraction, between 100 and 150 mL of 70% ethanol was added to 1 gm of the samples, and they were macerated for three days. The ethanolic extract obtained was filtered to remove solid residues, the filtrate was concentrated under reduced pressure on a rotary evaporator at 50 °C. The residue was resuspended in 30 mL of 70% ethanol that was subsequently centrifuged at 8000 g for 15 min to obtain a clarified supernatant. This was transferred to a 50 mL volumetric flask, adjusting its volume with ethanol. "Same procedure followed for each solvent such as hexane and chloroform" UV-Vis Spectrophotometric analysis For the calibration curve, cholesterol standards were prepared in glacial acetic acid, with concentrations between 0 and 10 mg/mL. Liebermann-Burchard reagent was added (6 mL), they were incubated for 10 min in a water bath at 37 °C. The absorbance was recorded in UV-Vis equipment at 650 nm, in a time range no longer than 10 min after the end of the incubation. Samples were prepared in 16 x 100 mm test tubes, taking 5 mL aliquot for each extract. A previous heating allowed the evaporation of the ethanol from each tube, then 100 μL of glacial acetic acid was added and stirred, to finally 6 mL of the Liebermann-Burchard reagent was added and homogenized in a Vortex. The samples were incubated for a period of 10 min in a water bath at 37 °C and after cooling, their absorbance were recorded at 650 nm (8).

Infrared Spectrophotometer with Fourier Transform (FTIR)

FTIR is most efficient method for identifying the many types of chemical bonds, or functional groups, found in compounds. The chemical bond can be inferred from the wavelength of light absorbed, as seen by the annotated spectrum. An infrared absorption spectrum can be used to determine the chemical bonds within a molecule. For FTIR analysis, extracts of each plant material were dried into a powder. Dried extract powder (10 mg) was encapsulated in 100 mg of KBr pellet to form translucent sample discs. Next, an FTIR spectroscope (Shimadzu, IR Affinity 1, Japan) with a scan range of 400 to 4000 cm^{-1} and a resolution of 4 cm^{-1} was loaded with the powdered plant sample (9).

Hydrogen Peroxide (H₂O₂)-induced Free Radical Scavenging Ability

A solution of 40 mM H_2O_2 was prepared in phosphate buffered saline (pH 7.4). In the dark, 1 mL of a 40 mM H_2O_2 solution was added to a range of plant extract concentrations (50–600 $\mu\text{g/mL}$). After ten minutes, the absorbance of hydrogen peroxide at 230 nm was measured using a UV-visible spectrophotometer in comparison to a blank solution. The phosphate buffer without H_2O_2 was present in the blank. The outcomes were contrasted with ascorbic acid's % scavenging capacity (100 $\mu\text{g/mL}$) as a reference. Every sample was tested three times. The percentage of scavenged H_2O_2 was calculated using the following equation (10).

$$\% \text{ of scavenged } H_2O_2 = [(Ac - As)/Ac] \times 100,$$

where Ac = absorbance of control phosphate buffer with H_2O_2 and As = absorbance in the presence of extract.





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Statistical analysis

(H₂O₂) free Radical Scavenging activity data was arranged in an Excel sheet. Percentage of the value were expressed as Mean ± S.D. Statistical significance of the results was evaluated by one-way ANOVA followed by DMRT (SPSS version 16.0, SPSS Inc., Cary, NC), and a P value < 0.05 was considered as significant.

RESULTS

Quantitative and qualitative analysis of phytochemicals in *T. arjuna* leaves extract

In leaves, aqueous and 70% ethanolic extract showed the active compounds presence in high concentration, such as, phenolic compounds and tannins, triterpenoids, saponins, flavonoids, alkaloids and proteins and Also, the active compounds presence in low concentration, such as phytosterol, carbohydrates, glycosides are shown Table-1 The rate of total flavonoid, phytosterols and phenolic content in different solvent of Hexane, Chloroform, Ethanol extracts of *T. arjuna* leaves were shown Table-2, Fig -1. Result of this study explore the comparison of total flavonoid, phytosterols and phenolic content in different solvent extracts of *T. arjuna* leaves

Analysis of phytochemicals by FTIR in *T. arjuna* leaves extract

The vibrational spectra of the secondary metabolites is regarded to be one of its unique physical properties. The absorption spectra of dried *T. arjuna* leaves collected within the range of 4000-400 cm⁻¹ are presented with functional group (Fig-2 and Table 3). FTIR spectra peak indicate the presence of different functional group relate to secondary metabolite of leaves extract

(H₂O₂) free Radical Scavenging activity in *T. arjuna* leaves extract

(H₂O₂) free Radical Scavenging activity was examined against *T. arjuna* leaves extract of aqueous and ethanol in different concentration (Table-4, Figure-3). *T. arjuna* leaves extracts in aqueous and ethanol showed evidence of free Radical Scavenging activity, which was concentration-dependent

DISCUSSION

The important phytochemicals found in medicinal plants and herbs are a range of primary and secondary plant metabolites that have been shown to have biological activities such as anti-inflammatory, anti-hyperglycemic, anti-microbial, and antidiabetic properties (11). Preliminary phytochemical screening was performed on newly produced extracts to detect the presence of flavonoids, phenolics, tannins, and alkaloids, phytosterols and within the mixture (12). The phytochemical profile from preliminary investigation revealed that the extracts of the formulation are enriched with a variety of essential phytochemicals including alkaloids, phenolics, tannins, flavonoid compounds, as depicted in Table 1 Total phenolic compounds, saponins and tannins were significantly high in the leaves (Table 2). The study describes that flavonoids, Phenolic content, Phytosterols can be extracted using various solvents, depending on their polarity (13) as observed in varies concentration Phytosterols, Alkaloids, carbohydrates, Flavonoids, phenolics are the most essential type of phytochemicals and have also been independently reported in several other investigations of various species of *Dillenia* and in fenugreeks and cumin herbs (11). Analyzed phytoconstituents in various extracts of the formulation have been reported to possess medicinal importance in various pathological conditions such as diabetes, cancer, and inflammation (14). chloroform extract of *T. arjuna* showed high amount of phenolic and flavonoid, Phytosterols content than the other solvent extracts. It can be seen from Table-2 that the total phenolic content rate 43.80.66 µg/mg in leaves extract of chloroform. while the lowest content was observed in ethonal extract. total flavonoid content rate 49.66 µg/mg in leaves extract. Free Phytosterols content rate 11.2 µg/mg in leaves extract of chloroform (15) The notable discrepancy in the flavonoid content and phenolic content results with the literature could be attributed to environmental factors such as pest exposure, illnesses, maturity time, climate, location, temperature, and fertility. Rainfall is also said to have an impact



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on the phenolic concentration. The variance in total phenolics in different the solvent obtained from plant extracts could be attributed to the existence of distinct phenolic compounds. It has been shown that flavonoid content is high in nearly all plant samples. Fig -1 indicate comparison of phytochemical in plant sample of leaves . Flavonoids content chloroform > ethanol > hexane , whereas phenolic compound chloroform > ethanol > hexane and phytosterol content chloroform > hexane > ethanol were presence respectively. Interpretation of the IR spectra was based on the identification of the functional groups represented by specific wave numbers and reported in the literature. Since FT-IR identifies specific chemical functional groups within polymeric compounds, it is able to give us an estimate of a plant's many molecular components. FTIR spectroscopy was used to identify the functional groups of bioactive components present in *Terminalia arjuna* leaves (Table 2 and Fig.2). FTIR spectrum confirmed the presence of hydroxyl group (O–H)- 1317; aldehyde (C–H)- 2847, alkenes (C=C)- 963, carboxyl (C=O)- 1734; nitrogen-containing group (N–O)- 1511, alkanes (C–C) 833, 2847; amines (N–H)-2361, alkynes (C≡C)- 1236; This above said functional group indicate the presence of phenols, carboxylic acids, alkyl halides, halogen, aliphatic amines, primary and secondary amines, esters, ether, aromatics, lipids, triglycerides, nitro compounds and these functional groups are the integral parts of various secondary metabolites such as alkaloids, favonoids, terpenoids, polyphenol and tannins (16,17). FTIR spectroscopy was used to identify the functional groups of bioactive components present in *Terminalia arjuna* leaves (Table 2 and Fig.2). the *Terminalia arjuna* leaves extract has the potential to reduce ROS such as H₂O₂.

The percentage ability of extract to scavenge H₂O₂ is shown in Table 3. The percentage of H₂O₂ scavenging activity against different concentrations of *Terminalia arjuna* leaves extract as well as ascorbic acid are shown. The H₂O₂ scavenging activity of extract increases in a concentration-dependent manner. The maximum percentage of scavenging activity is shown by 600 µg/mL of *Terminalia arjuna* leaves extract. The ascorbic acid showed good antioxidant activity in 200 µg/mL. This extract's strong polyphenolic component content is confirmed by its antioxidant activity.. Figure 2 shows the percentage of H₂O₂ scavenging activity of *Terminalia arjuna* extract and found to be statistically significant (p < 0.05) The present study provides the useful information about proximate composition of flavonoids and polyphenolic contents of *T.arjuna*, which are used for the therapeutic purposes. The low moisture content indicates good quality of plant material and its prolonged shelf life. It is interesting that the total phenolic content and flavonoid content did correlate well with the results from the H₂O₂ test (17) .The findings of this study support the fact that *T.arjuna* medicinal plants commonly consumed in India are promising sources of potential antioxidants

CONCLUSION

Phenolic and flavonoid content are rich in leaf of *T.arjuna* in different solvent extract .In this study, we documented a positive correlation between the total phenolic content and H₂O₂ scavenging activity confirmed its strong antioxidant nature that was earlier reported to be correlated with the presence of phenolic compounds . Thus, our data suggest that high antioxidant activities and high phenolic content, especially flavonoids, present in *Terminalia arjuna* may be possible contributors to its medicinal properties.

Conflict of interest: None

REFERENCES

1. Ravishankar B, Shukla VJ. Indian systems of medicine: a brief profile. African Journal of Traditional, Complementary and Alternative Medicines. 2007;4(3):319-37.
2. Zhang YJ, Gan RY, Li S, Zhou Y, Li AN, Xu DP et al. Antioxidant phytochemicals for the prevention and treatment of chronic diseases. Molecules. 2015 Dec;20(12):21138-56.
3. Amalraj A, Gopi S. Medicinal properties of Terminalia arjuna (Roxb.) Wight & Arn.: a review. Journal of traditional and complementary medicine. 2017 Jan 1;7(1):65-78.





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4. Biswas M, Biswas K, Karan TK, Bhattacharya S, Ghosh AK, Halder PK. Evaluation of analgesic and anti-inflammatory activities of Terminalia arjuna leaf. Journal of Phytology. 2011 Jan 19;3(1).
5. Mandal S, Patra A, Samanta A, Roy S, Mandal A, Mahapatra TD et al . Analysis of phytochemical profile of Terminalia arjuna bark extract with antioxidative and antimicrobial properties. Asian Pacific journal of tropical biomedicine. 2013 Dec 1;3(12):960-6.
6. Sharma G, Sharma V, Mishra T. Phytochemical analysis, high-performance liquid chromatography, and ex vivo antioxidant potential of a herbal fruit extract. phytochemical analysis. 2019;12(2).
7. Rajurkar NS, Hande SM. Estimation of phytochemical content and antioxidant activity of some selected traditional Indian medicinal plants. Indian journal of pharmaceutical sciences. 2011 Mar;73(2):146.
8. Araújo LB, Silva SL, Galvão MA, Ferreira MR, Araújo EL, Randau KP et al. Total phytosterol content in drug materials and extracts from roots of Acanthospermum hispidum by UV-VIS spectrophotometry. Revista Brasileira de Farmacognosia. 2013 Sep 1;23(5):736-42.
9. Mabasa XE, Mathomu LM, Madala NE, Musie EM, Sigidi MT. Molecular spectroscopic (FTIR and UV-Vis) and hyphenated chromatographic (UHPLC-qTOF-MS) analysis and in vitro bioactivities of the Momordica balsamina leaf extract. Biochemistry Research International. 2021 Sep 28;2021.
10. Keser S, Celik S, Turkoglu S, Yilmaz O, Turkoglu I. Hydrogen peroxide radical scavenging and total antioxidant activity of hawthorn. Chem J. 2012;2(1):9-12.
11. Singh PK, Singh J, Medhi T, Kumar A. Phytochemical screening, quantification, FT-IR analysis, and in silico characterization of potential bio-active compounds identified in HR-LC/MS analysis of the polyherbal formulation from Northeast India. ACS omega. 2022 Sep 7;7(37):33067-78.
12. Shaikh JR, Patil M. Qualitative tests for preliminary phytochemical screening: An overview. International Journal of Chemical Studies. 2020 Mar;8(2):603-8.
13. MS U, Ferdosh S, Haque Akanda MJ, Ghafoor K, AH R, Ali ME et al. Techniques for the extraction of phytosterols and their benefits in human health: A review. Separation Science and Technology. 2018 Sep 22;53(14):2206-23.
14. Kumar A, P N, Kumar M, Jose A, Tomer V, Oz E et al. Major phytochemicals: recent advances in health benefits and extraction method. Molecules. 2023 Jan 16;28(2):887.
15. Nayeem N, Imran M, Asdaq SM, Rabbani SI, Alanazi FA, Alamri AS et al. Total phenolic, flavonoid contents, and biological activities of stem extracts of Astragalus spinosus (Forssk.) Muschl. grown in Northern Border Province, Saudi Arabia. Saudi Journal of Biological Sciences. 2022 Mar 1;29(3):1277-82.
16. Mansoori A, Singh N, Dubey SK, Thakur TK, Alkan N, Das SN et al. Phytochemical characterization and assessment of crude extracts from Lantana camara L. for antioxidant and antimicrobial activity. Frontiers in Agronomy. 2020 Nov 12;2:582268.
17. Ralte L, Khiangte L, Thangjam NM, Kumar A, Singh YT. GC-MS and molecular docking analyses of phytochemicals from the underutilized plant, Parkia timoriana revealed candidate anti-cancerous and anti-inflammatory agents. Scientific Reports. 2022 Mar 1;12(1):3395.

Table.1- preliminary Phytochemical test

Name of the Phytochemical test	Observation in aqueous extract		Observation in 70% ethanol extract	
	bark	leaf	bark	leaf
Phytosterols	++	+	++	-
Triterpenoid	+	++	+	+
Saponins	+	++	+	++
Alkaloids	+	++	+	++
Carbohydrates	++	+	+	++
Flavonoids	+	++	+	+
Phenolic Compounds and Tannins	++	++	++	++
Lactones	-	+	-	+
Proteins	-	+	-	++





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Glycosides	+	-	+	-
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+ indicate presence, - indicate absent

Table-2: The total flavonoid ,phytosteols and phenolic content of different solvent extracts of *T. arjuna* leaf

S.No	Different solvent extracts of <i>T. arjuna</i> leaves	Leaves		
		Total Flavonoid content (µg/mg)	Total phenolic content (µg/mg)	Free Phytosterols µg/mg
1	Hexane	3.2±0.5	18.98±1.98	9.4±0.15
2	Chloroform	49.66±1.19	43.80±2.47	11.2±2.55
3	Ethanol	5.05±1.52	9.52±1.16	4.2±1.82

All the values were expressed as mean ± S.D. (N=3)

Table-3: FT-IR Spectra peak value of Terminalia arjuna leaves

Wave length	Description	Functional group
3567	OH group	polysaccharides
3264	OH group	alcohol
2917	C-H stretch	aliphatic asymmetry stretching vibrations
2847	C-H stretch	aldehyde
2361	N-H component	amines
1734.	O=C=O	carboxyl
1613.	C=C	α,β-unsaturated ketone
1511	N-O stretch or Aromatic skeletal vibration	nitro compound, Aromatic compound
1451	CH group	unknown
1372	CH bend	unknown
1317	OH Bend	alcohol
1236	CO stretch	alkyl aryl ether
1154.	C-O group	ether
1030	CO-O-CO	anhydride
963	C=C bending	alkene
889	C=C bending	alkene
833	C=C bending	Alkene trisubstituted
780.	C-H bend	1,3-disubstituted
658	C-H group	unknown

Table-4: Hydrogen Peroxide (H₂O₂) free Radical Scavenging activity

Name Plant extract	Concentration of aqueous extract				Concentration of ethanol extract			
	200 µg/ml	400 µg/ml	600 µg/ml	800 µg/ml	200 µg/ml	400 µg/ml	600 µg/ml	800 µg/ml
% of H ₂ O ₂ scavenged in	19.27±4.1	30.57±3.22	38.8±4.75	50.52±3.1	29.13±1.9	36.64±2.89	46.83±4.82	53.52±4.91





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Leaves							
Ascorbic acid		60.1±2.2				61.7±2.5	

All the data were expressed as mean ± S.D (n=3). indicates a significant (p<0.05)

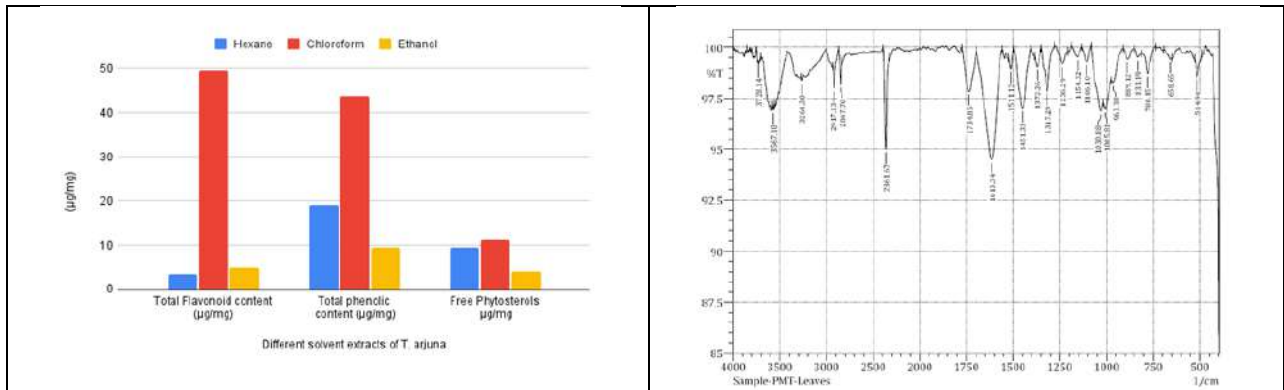


Fig -1 The total flavonoid ,phytosteols and phenolic content of different solvent extracts of *T. arjuna* leaves

Figure-2:FT-IR Spectra of Terminalia arjuna leaves

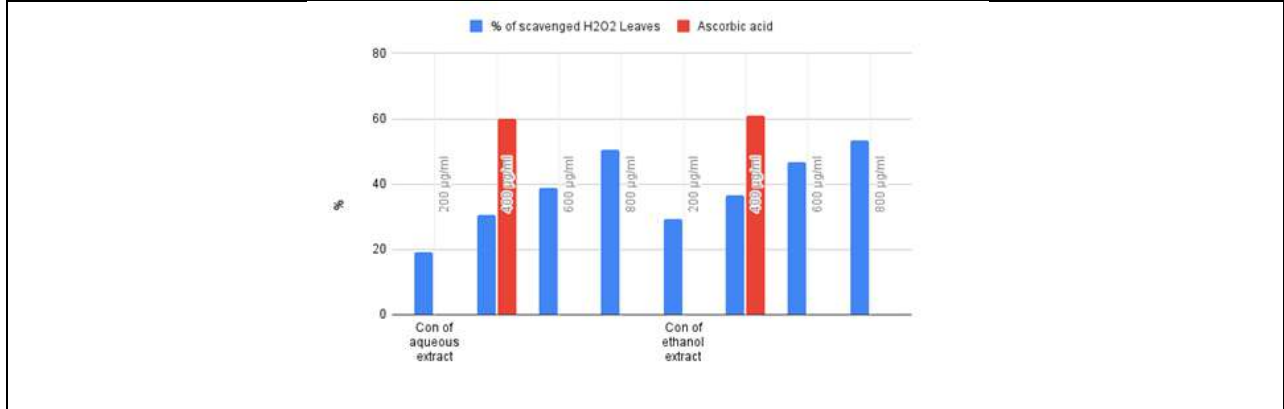


Figure.3: Hydrogen Peroxide (H₂O₂) free Radical Scavenging activity





Effect of Different Levels of Nitrogen in Combination with Nano Urea on Flowering, Yield and Quality of Crossandra (*Crossandra infundibuliformis* L.) cv. Lakshmi

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ABSTRACT

A study on the effect of different levels of nitrogen in combination with nano urea on flowering, yield and quality of crossandra (*Crossandra infundibuliformis* L.) cv. Lakshmi was carried out in the Department of Horticulture, Faculty of Agriculture, Annamalai University, Annamalai nagar during the year 2021-2023. Fourteen treatments with different levels of nitrogen and different concentrations of nano urea were formulated in Randomized Block Design. Among the different treatments, the treatment T₈ (100% PK + 50% N through urea + 0.4% Nano urea (3 sprays)) showed early spike emergence (37.54 days), time taken for 1st flowering (44.83 days) with an increase in number of spikes plant⁻¹ (36.27), spike length (14.21 cm) and number of flowers spike⁻¹ (39.21). The increase in 100 flower weight (8.62 g), flower yield plant⁻¹ (51.03 g), flower yield plot⁻¹ (974.76 g plot⁻¹), estimated flower yield hectare⁻¹ (32.49 q ha⁻¹) and quality attributes like xanthophyll content (69.42 mg g⁻¹), carotenoid content (57.76 mg g⁻¹), shelf life of flowers (74.88 hours), longevity of flower in the plant (95.52 hours) and flowers with an excellent quality of visual scoring (9.16) were also observed the maximum in the treatment T₈(100% PK + 50% N through urea + 0.4% Nano urea (3 sprays)). The treatment control (T₁) had the lowest value for all the yield and quality attributes.

Keywords: Lakshmi crossandra, nitrogen, nano urea, flowering, yield and quality.



**Gowtham and Karuppaiah****INTRODUCTION**

Ornamental flowering plants are highly valued for their attractive look and appearance. One such ornamental flowering plant is crossandra bearing bright orange and yellow coloured flowers belongs to the family “Acanthaceae” and the genus *Crossandra* consists of about 50 species. *Crossandra*, also known as “fire cracker plant” because the seed pods that are usually formed after flowering tend to explode under high humid conditions (Meghana *et al.*, 2022). Flowers of crossandra are light in weight and have bright orange coloured flowers which make a good contrast with fragrant jasmine flowers for the preparation of flower string or garland, used in religious offerings, hair adornments, garland, venis and also suitable for garden display. The plant is also popular as potted ornamental in Sweden, Denmark and Hungary (Bharathi *et al.*, 2018). There is an adequate scope to enhance the production of crossandra by adopting modern crop management practices. One such approach is application of nano fertilizers and reducing the usage of conventional fertilizers. Numerous modern horticulturists give more attention to nano fertilizers. But since no enough studies have been carried out to evaluate the effect of nano urea and nitrogen on crossandra so far. This study aims to explore the effect of different levels of nitrogen in combination with nano urea on flowering, yield and quality of crossandra (*Crossandra infundibuliformis* sL.) cv. Lakshmi.

MATERIALS AND METHODS

This study was carried out in the Floriculture unit, Department of Horticulture, Faculty of Agriculture, Annamalai University, Annamalai Nagar, Tamil Nadu during the year 2021-2023. The experiment was laid out in Randomized Block Design with 14 treatments and 3 replications. The treatments were T₁ (Control), T₂ (100% NPK), T₃ (100% PK + 75% N through urea + 0.2% Nano urea (3 sprays)), T₄ (100% PK + 75% N through urea + 0.3% Nano urea (3 sprays)), T₅ (100% PK + 75% N through urea + 0.4% Nano urea (3 sprays)), T₆ (100% PK + 50% N through urea + 0.2% Nano urea (3 sprays)), T₇ (100% PK + 50% N through urea + 0.3% Nano urea (3 sprays)), T₈ (100% PK + 50% N through urea + 0.4% Nano urea (3 sprays)), T₉ (100% PK + 25% N through urea + 0.2% Nano urea (3 sprays)), T₁₀ (100% PK + 25% N through urea + 0.3% Nano urea (3 sprays)), T₁₁ (100% PK + 25% N through urea + 0.4% Nano urea (3 sprays)), T₁₂ (100% PK + 0.2% Nano urea (3 sprays)), T₁₃ (100% PK + 0.3% Nano urea (3 sprays)) and T₁₄ (100% PK + 0.4% Nano urea (3 sprays)). Healthy, uniform sized rooted cuttings were planted in the pits with spacing 60 x 40 cm for an area of about 4 cents. For 100 % NPK = 26 g of urea, 37 g of SSP and 30 g of MOP was applied. Similarly, for 75 % N = 20 g of urea, 50 % of N = 13 g of urea and 25 % of N = 6.5 g of urea were applied. First irrigation was given immediately after planting. Subsequent irrigations were given at 7 days interval. Application of nano urea were done by foliar application. The prepared solution was sprayed three times in the field on 45th, 60th and 75th DAP. Uniform cultural practices were maintained for all the treatments. The observations on yield parameters like early spike emergence, time taken for 1st flowering, number of spikes plant⁻¹, spike length, number of flowers spike⁻¹, 100 flower weight, flower yield plant⁻¹, flower yield plot⁻¹, estimated flower yield hectare⁻¹ and quality parameters like xanthophyll content, carotenoid content, shelf life of flowers, longevity of flower in the plant and visual scoring were recorded on five randomly selected tagged plants from each treatment in each replication. The data on various parameters were analysed statistically as per the procedure suggested by Panse and Sukhatme (1978).

RESULTS AND DISCUSSION

The results of present study revealed that all the treatments differed significantly on improving the flowering, yield and quality of crossandra (*Crossandra infundibuliformis* L.) cv. Lakshmi over control.

Flowering parameters

The data on the effect of different levels of nitrogen in combination with nano urea on flowering characters of crossandra are presented in Table 1. The minimum number of days taken for 1st spike emergence (37.54 days) and 1st flowering in a spike (44.83 days) were observed under the treatment T₈ (100% PK + 50% N through urea + 0.4%



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Nano urea (3 sprays), followed by T₇ (100 % PK + 50 % N through urea + 0.3 % Nano urea (3 sprays)) that required 38.71 days for 1st spike emergence and 45.64 days for 1st flowering in a spike. The maximum days for 1st spike emergence (49.16 days) and more number of days for 1st flowering in spike (57.19 days) were noticed under the treatment T₁ (control). The early spike emergence and flowering could be attributed to the reason that optimum supply of nutrients promoted better plant growth and consequently plants could put up requisite vegetative in lesser time due to which spike emergence and flowering was advanced. It was similar to the findings as reported by Dorajeerao *et al.* (2012) in annual chrysanthemum, Senapati *et al.* (2020) in floral chrysanthemum and Pal *et al.* (2020) in tuberose. The maximum number of spikes in a plant (36.27) and number of flowers per spike (39.21) were observed in the treatment T₈ (100% PK + 50% N through urea + 0.4% Nano urea (3 sprays)), followed by T₇ (100% PK + 50% N through urea + 0.3% Nano urea (3 sprays)) with number of spikes per plant (35.09) and number of flowers per spike (38.18). The minimum number of spikes in a plant (21.65) and flowers per spike (26.54) were observed under control (T₁). At different nitrogen levels, the vegetative growth of plant and more accumulation of food reserves are diverted to flower bud differentiation and foliar spray of nano urea to crop canopy resulted in more number of spikes per plant. The increased number of spikes under optimum dose of nitrogen may be attributed to more number of flowers per spike. The findings were comparable with Sendhilnathan and Manivannan (2019) in tuberose, Gowthami *et al.* (2018) in crossandra and Priyanka *et al.* (2018) in crossandra. Application of 100% PK + 50% N through urea + 0.4% Nano urea (3 sprays) (T₈) resulted in the maximum spike length (14.21 cm), followed by T₇ (13.09 cm). The minimum length of the spike was observed in control, T₁ (4.75 cm) (Figure.1). The increase in spike length might be due to the fact that N helped in increasing the amount of assimilates that are needed for improvement in spike quality. Similar results were reported by Dalvi *et al.* (2022) in tuberose.

Yield parameters

The data on the effect of different levels of nitrogen in combination with nano urea on yield characters of crossandra are presented in Table 2. The 100 flower weight (8.62 g), flower yield plant⁻¹ (51.03 g plant⁻¹), flower yield plot⁻¹ (974.76 g plot⁻¹) and estimated flower yield hectare⁻¹ (32.49 q ha⁻¹) were recorded the maximum in T₈ (100% PK + 50% N through urea + 0.4% Nano urea (3 sprays)), followed by the treatment T₇ (100% PK + 50% N through urea + 0.3% Nano urea (3 sprays)) with the values of 100 flower weight (8.48 g), flower yield plant⁻¹ (50.01 g plant⁻¹), flower yield plot⁻¹ (944.15 g plot⁻¹) and estimated flower yield hectare⁻¹ (31.47 q ha⁻¹). The minimum 100 flower weight (6.31 g), flower yield per plant (29.50 g plant⁻¹), flower yield per plot (623.40 g plot⁻¹) and estimated flower yield per hectare (20.78 q ha⁻¹) were noticed in control (T₁). The increase in 100 flower weight and flower yield was due to larger size of the flower and more number of flowers spike⁻¹. The optimum supply of nutrients to the crop at the different growth stages, ultimately increasing the carbohydrates assimilates which leads to acceleration in flower weight, flower yield plant⁻¹ and flower yield plot⁻¹. The present findings are in close affirmative with Priyanka *et al.* (2018) in crossandra, Mangroliya *et al.* (2021) in jasmine and Venkatesh *et al.* (2022) in African marigold.

Quality parameters

The data on the effect of different levels of nitrogen in combination with nano urea on quality characters of crossandra are presented in Table 3. With regard to quality aspects *viz.*, xanthophyll content (69.42 mg g⁻¹) and carotenoid content (57.76 mg g⁻¹) were found to be the maximum in the treatment consists of T₈ (100% PK + 50% N through urea + 0.4% Nano urea (3 sprays)) (Figure 2). The treatment T₈ is followed by T₇ with the values of xanthophyll content (67.23 mg g⁻¹) and carotenoid content (55.78 mg g⁻¹). The minimum xanthophyll content (39.04 mg g⁻¹) and carotenoid content (24.58 mg g⁻¹) were found in the treatment T₁ which is control. The increase in xanthophyll and carotenoid content of flowers might be due to higher carbohydrate, essentiality of major nutrients and enzymes deposition in flower cells. Similar results were obtained by Karuppaiah and Krishna (2005) in French marigold. The treatment T₈ (100% PK + 50% N through urea + 0.4% Nano urea (3 sprays)) recorded the maximum shelf life (74.88 hours), longevity of flower in the plant (95.52 hours) and visual scoring (9.16). It was then followed by T₇ with the values of shelf life (72.99 hours), longevity of flower in the plant (93.03 hours) and visual coring (9.01). The treatment control (T₁) recorded the minimum shelf life (49.15 hours), longevity of flower in the plant (61.85 hours) and visual scoring (6.10). Increased shelf life might be attributed to the application of nitrogen as nano urea. As a result, slow and steady release of nutrient to the plant would have helped in maintenance of turgor in the leaf and





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flower which in-turn enhanced the longevity of the flower. Better quality of crossandra flower might be due to the appropriate combination of nutrient applied which ultimately enhanced the appearance of flowers. The results were in agreement with the findings of Gopitha *et al.* (2021) in nerium. From the study, the treatment T₈ (100% PK + 50% N through urea + 0.4% Nano urea (3 sprays)) showed improved flowering parameters with better yield and excellent quality of flowers which in-turn increases the market value. Therefore, it is concluded that application of 100% PK + 50% N through urea + 0.4% nano urea foliar spray (3 sprays) (T₈) was found to be the best combination for obtaining good yield, excellent quality flowers and better profit.

REFERENCES

1. Bharathi, T. U., T. R. Manjunatha and C. Aswath. 2018. Assessing the suitability of crossandra (*Crossandra infundibuliformis* (L.) Nees) as potted plant. International Journal of Current Microbiology and Applied Sciences, 7(12):1028-35.
2. Dalvi, N. V., B. R. Salvi, C. D. Pawar, V. G. Salvi, M. M. Burondkar, J. S. Dhekale and R. G. Khandekar. 2022. Response of spacing and nitrogen levels on tuberose (*Polianthes tuberosa* L.) cv. Pune Single. The Pharma Innovation Journal, 11(3): 1599-1603.
3. Dorajeerao, A. V. D., A. N. Mokashi, V. S. Patil, C. K. Venugopal, S. Lingaraju and R.V. Koti. 2012. Effect of graded levels of nitrogen and phosphorus on growth and yield of garland chrysanthemum (*Chrysanthemum coronarium* L.). Karnataka Journal of Agricultural Sciences, 25(2): 229-231.
4. Gopitha, G., M. Kannan, A. Sankari and R. Santhi. 2021. Effect of integrated nutrient management on flower quality and physiological parameters of nerium (*Nerium oleander* L.). Journal of Pharmacognosy and Phytochemistry, 10(1): 1847-1851.
5. Gowthami, L., M. B. Nageswararao, K. Umajyothi and K. Umakrishna. 2018. Effect of different levels of nitrogen and potassium on yield attributes of crossandra (*Crossandra infundibuliformis* L.). Plant Archives, 18(1): 275-278.
6. Karuppaiah, P. and G. Krishna. 2005. Response of spacings and nitrogen levels on growth, flowering and yield characters of French marigold (*Tagetes patula* Linn.). Journal of Ornamental Horticulture, 8(2): 96-99.
7. Mangroliya, R., S. Bhatt, B. M. Tandel, H. Patel, D. Bhatt and G. Patel. 2021. Nutrient management strategies through split application for optimizing growth, quality, yield and nutrient use efficiency in Jasmine. The Pharma Innovation Journal, 10(7): 468-4972.
8. Meghana, K., D. V. S. Raju, A. D. Rao, M. R. Babu and P. Subbramma. 2022. Influence of growth retardants on growth and flowering of Crossandra (*Crossandra infundibuliformis*) under potted conditions. The Pharma Innovation Journal, 11(8): 1302-1304.
9. Pal, V., N. Chandra, V. Kumar, and O. Singh. 2020. Growth, flowering and bulb yield of tuberose (*Polianthes tuberosa* L.) cv. Mexican Single as affected by nitrogen and phosphorus under varying spacing. Progressive Agriculture, 20(1 and 2): 188-190.
10. Panse, V. G. and P. V. Sukhatme. 1978. Statistical methods for agricultural workers. Indian Council of Agricultural Research, New Delhi (India).
11. Priyanka, T. K., B. S. Kamble, R. K. Subiya, R. W. Anuradha and V. D. Gasti. 2018. Interactive study of spacing and different levels of nutrients on flowering and yield attributes of crossandra (*Crossandra undulaefolia* Salis b.). Journal of Pharmacognosy and Phytochemistry, 7(1): 487-490.
12. Senapati, S. K., T. K. Das and G. Pandey. 2020. Effect of nitrogen, phosphorus and potassium level on morphological characteristics of chrysanthemum (*Chrysanthemum morifolium* Ramat) cv. Bidhan Madhuri. International Journal of Current Microbiology and Applied Sciences, 9(9): 283-3288.
13. Sendhilnathan, R. and K. Manivannan. 2019. Effect of graded levels of nitrogen and phosphorus on yield and quality of tuberose (*Polianthes tuberosa* L.). Annals of Plant and Soil Research, 21(3): 261-264.
14. Venkatesh, M., K. K. Babu, P. Prasanth, D. Lakshminarayana and S. P. Kumar. 2022. Study on effect of different levels of nitrogen in combination with nano urea on growth and yield of marigold (*Tagetes erecta* L.) cv. Pusa NarangiGaiinda. The Pharma Innovation Journal, 11(11): 1313-1317.





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Table 1. Effect of different levels of nitrogen in combination with nano urea on flowering characters of crossandra (*Crossandra infundibuliformis* L.) cv. Lakshmi

Treatments	Days taken for 1 st spike emergence (days)	Days taken for 1st flowering (days)	No. of spikes plant ⁻¹	No. of flowers Spike ⁻¹
T ₁	49.16	57.19	21.65	26.54
T ₂	42.88	50.66	28.72	33.66
T ₃	41.95	49.48	29.73	34.58
T ₄	41.43	49.27	30.48	35.12
T ₅	39.68	46.69	33.63	37.19
T ₆	40.53	48.08	31.68	36.07
T ₇	38.71	45.64	35.09	38.18
T ₈	37.54	44.83	36.27	39.21
T ₉	45.24	53.19	26.21	31.36
T ₁₀	44.75	52.91	26.72	31.79
T ₁₁	43.82	51.67	27.74	32.72
T ₁₂	48.09	56.21	22.63	28.19
T ₁₃	47.23	55.12	23.60	29.44
T ₁₄	46.28	54.25	24.58	30.46
S. Ed	0.33	0.29	0.48	0.46
CD (p=0.05)	0.67	0.58	0.96	0.93

Table 2. Effect of different levels of nitrogen in combination with nano urea on yield characters of crossandra (*Crossandra infundibuliformis* L.) cv. Lakshmi

Treatments	100 flower weight (g)	Flower yield plant ⁻¹ (g plant ⁻¹)	Flower yield plot ⁻¹ (g plot ⁻¹)	Estimated flower yield hectare ⁻¹ (q ha ⁻¹)
T ₁	6.31	29.50	623.40	20.78
T ₂	7.57	41.05	830.18	27.67
T ₃	7.73	43.83	848.67	28.32
T ₄	7.78	44.77	864.65	28.82
T ₅	8.28	48.79	915.63	30.52
T ₆	8.09	46.56	888.39	29.61
T ₇	8.48	50.01	944.15	31.47
T ₈	8.62	51.03	974.76	32.49
T ₉	7.22	36.24	773.16	25.77
T ₁₀	7.26	37.22	787.59	26.25
T ₁₁	7.38	39.81	811.82	27.06
T ₁₂	6.45	32.44	654.92	21.83
T ₁₃	6.69	32.92	699.54	23.32
T ₁₄	6.84	34.82	737.48	24.58
S. Ed	0.02	0.58	9.81	0.26
CD (p=0.05)	0.05	1.17	19.72	0.54





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Table 3. Effect of different levels of nitrogen in combination with nano urea on quality characters of crossandra (*Crossandra infundibuliformis* L.) cv. Lakshmi

Treatments	Xanthophyll content (mg g ⁻¹)	Carotenoid content (mg g ⁻¹)	Shelf life of flower (hours)	Longevity of flower in the plant (hours)	Visual coring
T ₁	39.04	24.58	49.15	61.85	6.10
T ₂	54.23	43.05	63.50	80.37	7.99
T ₃	56.32	46.24	65.51	83.40	8.27
T ₄	57.91	47.23	66.44	84.64	8.44
T ₅	64.14	53.62	71.21	90.30	8.87
T ₆	61.30	50.78	69.02	87.76	8.69
T ₇	67.23	55.78	72.99	93.03	9.01
T ₈	69.42	57.76	74.88	95.52	9.16
T ₉	49.01	34.53	57.39	72.96	7.14
T ₁₀	50.20	35.73	58.42	74.14	7.25
T ₁₁	52.24	39.27	60.76	76.85	7.58
T ₁₂	41.19	26.31	50.97	64.42	6.26
T ₁₃	44.20	28.49	52.67	67.20	6.75
T ₁₄	47.09	31.56	54.81	69.77	6.99
S. Ed	0.91	0.78	0.70	0.96	0.06
CD (p=0.05)	1.84	1.57	1.41	1.93	0.13

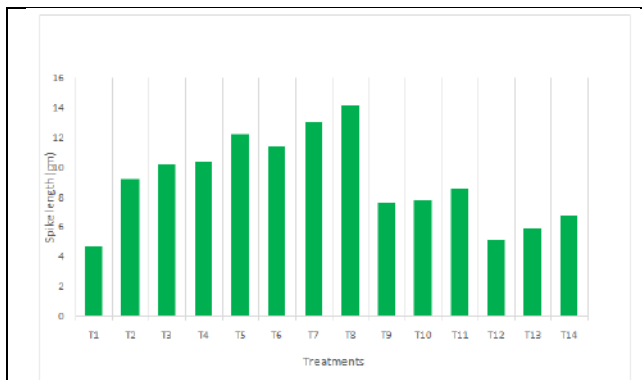


Figure 1. Effect of different levels of nitrogen in combination with nano urea on spike length (cm) of crossandra (*Crossandra infundibuliformis* L.) cv. Lakshmi

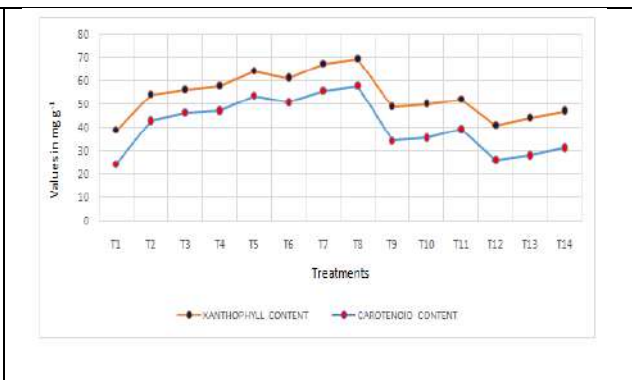


Figure 2. Effect of different levels of nitrogen in combination with nano urea on xanthophyll content (mg g⁻¹) and carotenoid content (mg g⁻¹) of crossandra (*Crossandra infundibuliformis* L.) cv. Lakshmi





Advancements in Protein-based Therapies for Cancer: A Comprehensive Analysis

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ABSTRACT

Protein-based therapies represent a groundbreaking class of treatments in oncology, providing high specificity and potency by targeting unique molecular pathways essential for cancer progression. These therapies, including monoclonal antibodies, fusion proteins, cytokines, and peptide-based therapies, offer a precise approach to cancer treatment, focusing on specific molecular markers to minimize collateral damage to normal tissues and enhance patient outcomes. They embody a shift from traditional therapies by offering tailored treatment options, addressing drug resistance, and improving the quality and longevity of life for cancer patients. With advances in biotechnology and molecular biology, protein-based therapies have evolved, offering a diverse arsenal for combating cancer through targeted mechanisms such as apoptosis induction, immune system modulation, and direct action on cancer cells. Clinical applications demonstrate significant advancements in treating various cancers, with ongoing trials exploring innovative approaches like immune checkpoint inhibitors and CAR-T cell therapy. Despite challenges such as drug resistance and side effects, the future of protein-based therapies in oncology looks promising, with potential in personalized medicine and combination therapies, underscored by advancements in protein engineering and drug delivery systems.

Keywords: Protein-based therapies, Oncology, Monoclonal antibodies, Targeted treatment, Drug resistance, Personalized medicine





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INTRODUCTION

Protein-based therapies represent a sophisticated class of treatments that leverage biologically active proteins to target specific pathological processes. Unlike traditional small-molecule drugs, these large biomolecules can exhibit high specificity and potency, with a range of mechanisms including direct action on cancer cells, modulation of the immune system, or alteration of the tumour microenvironment[1]. Key categories within this domain encompass monoclonal antibodies, fusion proteins, cytokines, and peptide-based therapies, each designed to exploit distinct molecular pathways critical to cancer progression. The rationale behind employing proteins as therapeutic agents is rooted in their pivotal roles in cellular function and communication, offering a versatile platform for designing interventions that can disrupt the aberrant signalling networks fundamental to cancerous growth and metastasis [2].

Overview of their role in Cancer Treatment

In the realm of oncology, protein-based therapies have ushered in a new era of precision medicine, targeting specific molecular markers unique to cancer cells. This specificity enables a focused attack on cancer cells while sparing normal tissues, thereby reducing collateral damage and side effects associated with conventional chemotherapy and radiation[3,4]. These therapies can be categorized based on their action mechanisms: directly targeting cancer cells to induce apoptosis, modulating the immune system to recognize and destroy cancer cells, or interfering with specific molecular pathways crucial for tumour growth and survival [5]. Their integration into cancer care has significantly improved patient outcomes across various cancer types, offering therapeutic options where conventional modalities may fall short. Particularly in cancers with identifiable molecular targets, protein-based therapies provide a tailored approach, enhancing the efficacy and precision of cancer treatment [6,7].

Significance and Potential Benefits Over Traditional Treatments

Protein-based therapies represent a paradigm shift in cancer treatment, addressing many limitations of traditional therapies. Their targeted nature translates to higher efficacy and fewer off-target effects, offering a better safety profile and improving patient quality of life. This precision not only enhances therapeutic outcomes but also paves the way for personalized medicine, where treatments are tailored to the individual's genetic and molecular cancer profile [8]. The protein-based therapies can overcome some mechanisms of drug resistance inherent to conventional chemotherapy, providing new avenues for treatment in refractory cancer cases. Their ability to be combined with other therapeutic modalities can lead to synergistic effects, broadening the scope of effective cancer treatments [9]. Despite higher initial costs, the long-term benefits of improved survival rates and reduced side effects underscore the value of these therapies in modern oncology, marking a significant step forward in the quest to manage and potentially cure cancer [10].

BACKGROUND AND DEVELOPMENT

Historical Perspective on Protein-Based Therapies in Oncology

The genesis of protein-based therapies in oncology can be traced back to the early 20th century, with the advent of serum therapy and the development of vaccines. However, it wasn't until the latter part of the century that significant strides were made in this domain, particularly with the emergence of monoclonal antibody technology in the 1970s [11,12]. This innovation provided a method to produce antibodies specific to cancer cell antigens, marking the inception of targeted cancer therapy. The approval of the first monoclonal antibody for cancer treatment, Rituximab, in 1997, heralded a new era in oncology [13,14]. Subsequently, the field has seen an expansion in the variety of protein-based therapies, including cytokine therapies, growth factor inhibitors, and oncolytic virus therapies. These advancements have been pivotal in transitioning from a one-size-fits-all approach to more individualized, targeted interventions, fundamentally altering the landscape of cancer treatment [15,16].



**Mallikarjuna Gandla and Niranjana Babu Mudduluru****Advances in Biotechnology and Molecular Biology**

The blossoming of protein-based therapies in oncology has been underpinned by monumental advances in biotechnology and molecular biology. Key developments include recombinant DNA technology, which enables the production of humanized proteins in host cells, and hybridoma technology, which facilitates the creation of monoclonal antibodies [17]. High-throughput sequencing and proteomics have provided deep insights into cancer biology, identifying novel therapeutic targets. Techniques like CRISPR/Cas9 and advanced protein engineering have further enhanced the specificity and efficacy of protein-based therapies. The integration of bioinformatics and systems biology has accelerated the identification and validation of targets, allowing for a more nuanced understanding of the complex interactions within cancer cells and their microenvironment. These technological advancements have not only expanded the arsenal of protein-based therapies but have also improved their precision, efficacy, and safety profiles [18,19].

Comparison with Traditional Cancer Treatments

While traditional cancer treatments like chemotherapy and radiation have been mainstays in oncology, protein-based therapies offer distinct advantages. Chemotherapy, characterized by its cytotoxic action on rapidly dividing cells, does not discriminate between cancerous and healthy cells, leading to broad systemic toxicity [20,21]. Radiation therapy, although more localized, can still damage surrounding healthy tissues. In contrast, protein-based therapies provide targeted action, focusing on specific molecular targets unique to cancer cells, thereby minimizing collateral damage to normal cells. This specificity reduces the prevalence and severity of side effects, improving patient tolerance and quality of life [22,23]. Moreover, protein-based therapies can be engineered to overcome drug resistance mechanisms, a common challenge with traditional treatments. They also offer potential for combinational use with other therapies, enhancing efficacy and addressing the heterogeneity and complexity of cancer. Despite these advantages, it's essential to acknowledge that protein-based therapies are not universally effective for all cancers or patients, highlighting the need for ongoing research and personalized treatment strategies [24].

Monoclonal Antibodies in Cancer Therapy

Monoclonal antibodies (mAbs) are engineered immunoproteins that bind to specific antigens, often overexpressed on cancer cells, to induce an immune response or directly inhibit tumor growth. Their mechanism of action includes triggering cell death through apoptosis, blocking growth factor receptors, and engaging immune cells for antibody-dependent cellular cytotoxicity [25,26]. For instance, Trastuzumab targets the HER2 receptor in breast cancer, disrupting cell signalling and proliferation. Rituximab, targeting CD20 on B cells, is used in lymphoma treatment, promoting cell lysis. These examples highlight mAbs' role in offering precision in targeting cancer cells, improving therapeutic outcomes, and reducing off-target effects [27].

Cancer Vaccines

Cancer vaccines stimulate the immune system to recognize and combat cancer cells. Therapeutic cancer vaccines, like Sipuleucel-T for prostate cancer, are designed to induce an immune response against cancer-specific antigens. Prophylactic vaccines, such as the HPV vaccine, prevent virus-associated cancers by inducing immunity against the causative agent. These vaccines represent a proactive and personalized approach, enhancing the immune system's ability to target and eliminate cancer cells, and are continually being developed for various cancer types [28,30].

Oncolytic Virus Therapy

Oncolytic virus therapy employs genetically modified viruses that selectively infect and lyse cancer cells while sparing normal tissue. These viruses can be engineered to express therapeutic genes, enhancing anti-tumor immunity. Talimogene laherparepvec (T-VEC) for melanoma exemplifies this approach, where the herpes simplex virus is modified to target tumor cells, inducing local and systemic immune responses against tumors. This therapy signifies an innovative strategy that combines direct oncolysis and immunomodulation to combat cancer [31,32].



**Mallikarjuna Gandla and Niranjana Babu Mudduluru****Immune Checkpoint Inhibitors**

Immune checkpoint inhibitors disrupt the interactions between cancer cells and immune checkpoints, which cancer exploits to evade immune surveillance. By blocking checkpoint proteins like PD-1 or CTLA-4, these agents reinvigorate T-cell function, enhancing the immune system's ability to recognize and destroy cancer cells. Nivolumab (PD-1 inhibitor) and Ipilimumab (CTLA-4 inhibitor) are examples that have shown efficacy in several cancers, including melanoma and non-small cell lung cancer, marking a significant advancement in immunotherapy by leveraging the body's own defense mechanisms against cancer [33,34].

Cytokine Therapy

Cytokine therapy involves the use of signaling proteins, cytokines, to modulate the immune system in fighting cancer. Interferons and interleukins are the main types used, with Interferon-alpha being effective in treating hematologic malignancies and melanoma by inhibiting cell proliferation and inducing immune responses. Interleukin-2 promotes T-cell proliferation and activity, showing benefits in renal cell carcinoma and melanoma. While cytokine therapy can be potent, its application is often limited by systemic toxicities, necessitating careful patient selection and management [35-37].

MECHANISM OF ACTION**Protein-Based Therapies Target Cancer Cells**

Protein-based therapies target cancer cells through mechanisms that exploit the unique molecular features of these cells. Monoclonal antibodies, for instance, are designed to recognize specific antigens expressed on the surface of cancer cells. Once bound, these antibodies can induce direct antitumor effects, such as blocking growth factor receptors essential for tumour proliferation. For example, HER2-targeted therapies inhibit the HER2 receptor's signalling pathways, leading to reduced cell division and increased apoptosis in breast cancer cells overexpressing HER2 [38]. Another targeting mechanism is the recruitment of the immune system to attack cancer cells. Antibodies can engage immune cells through their Fc regions, initiating processes like antibody-dependent cellular cytotoxicity (ADCC), where natural killer cells are drawn to the antibody-coated cancer cells, leading to their destruction [39]. Additionally, some protein-based therapies, such as bispecific T cell engagers (BiTEs), bridge cancer cells and T cells, facilitating a targeted immune response against the tumour. On the other hand, oncolytic viruses selectively infect and lyse cancer cells, exploiting their altered signalling pathways and cellular environments that favour viral replication, leading to tumour cell destruction and the release of tumour antigens, which further stimulate an immune response against the cancer [40,41].

Role of Proteins in Cell Signalling, Apoptosis, and Immune System Modulation

Proteins play pivotal roles in cell signalling, acting as messengers that convey signals from the cell surface to the interior, orchestrating responses to various stimuli. In cancer, this signalling is often dysregulated, with proteins like growth factor receptors being overactive, leading to uncontrolled cell division. Protein-based therapies can interrupt these aberrant signalling pathways, restoring regulated cell growth and inducing apoptosis [42]. Apoptosis, or programmed cell death, is a vital process that eliminates damaged or unwanted cells. In cancer, the apoptotic machinery is often impaired, enabling cancer cell survival. Protein-based therapies can induce apoptosis in cancer cells by activating or restoring the function of pro-apoptotic proteins or inhibiting anti-apoptotic proteins, thereby tipping the balance towards cell death [43]. In immune system modulation, proteins such as cytokines and checkpoint inhibitors play crucial roles. Cytokines can boost the immune response against tumours by promoting the activation and proliferation of immune cells. Checkpoint inhibitors block proteins that cancer cells use to evade immune detection, effectively uncovering the cancer to the immune system. This unmasking allows T cells to recognize and destroy cancer cells, leveraging the body's own defence mechanisms in the fight against cancer [44]. Through these multifaceted roles, proteins are integral to maintaining cellular homeostasis, and their targeted modulation provides a powerful strategy in cancer therapy, offering specificity and efficacy in targeting tumour cells while minimizing harm to normal tissues [45].



**Mallikarjuna Gandla and Niranjan Babu Mudduluru****CLINICAL APPLICATIONS****Case Studies of Successful Protein-Based Therapies in Cancer Treatment**

A successful protein-based therapy is Trastuzumab (Herceptin), a monoclonal antibody used to treat HER2-positive breast cancer. Clinical studies have demonstrated that when combined with chemotherapy, Trastuzumab significantly improves survival rates compared to chemotherapy alone. It targets the HER2 receptor, a protein overexpressed in a subset of breast cancers, inhibiting cancer cell growth and survival. Its success has transformed the treatment landscape for HER2-positive breast cancer patients, offering a targeted therapy that reduces recurrence risk and improves outcomes. Another notable example is Rituximab (Rituxan), a monoclonal antibody used in the treatment of non-Hodgkin lymphoma (NHL) and chronic lymphocytic leukemia (CLL). Rituximab targets the CD20 antigen on B cells, leading to their destruction. Its introduction has significantly improved survival rates in NHL and CLL, becoming a cornerstone in the treatment regimens for these malignancies [46,47].

Current Clinical Trials and Outcomes

In the realm of current clinical trials, a significant focus has been on immune checkpoint inhibitors. Pembrolizumab and Nivolumab, targeting the PD-1 pathway, have shown promising results in various cancers, including melanoma, non-small cell lung cancer (NSCLC), and kidney cancer. These drugs enhance the immune system's ability to detect and destroy cancer cells. Recent trials have demonstrated their efficacy in extending survival and improving the quality of life for patients with advanced-stage cancers, often with durable responses [48]. Another area of active research is CAR-T cell therapy, a type of treatment where a patient's T cells are genetically engineered to better recognize and attack cancer cells. Tisagenlecleucel (Kymriah) and Axicabtagene ciloleucel (Yescarta) are examples of CAR-T cell therapies that have shown success in treating certain types of blood cancers, such as acute lymphoblastic leukemia (ALL) and diffuse large B-cell lymphoma (DLBCL). Clinical trials have reported remarkable remission rates in patients who had previously exhausted other treatment options, highlighting the potential of this innovative approach in refractory or relapsed cancers [49].

CHALLENGES AND LIMITATIONS**Drug Resistance and Its Implications**

Drug resistance in cancer treatment, particularly concerning protein-based therapies, presents a significant challenge in the clinical management of cancer. Resistance mechanisms can arise through various biological pathways, including genetic mutations in the target protein, altered drug metabolism, or compensatory activation of alternative signalling pathways [50]. For example, mutations in the HER2 receptor can reduce the binding affinity of Trastuzumab, diminishing its therapeutic efficacy in breast cancer treatment [51]. Similarly, changes in the expression of PD-1/PD-L1 can impact the effectiveness of immune checkpoint inhibitors. The development of resistance not only compromises the efficacy of current treatments but also necessitates the continuous development of novel therapeutic strategies, such as combination therapies or next-generation drugs, to overcome or circumvent resistance mechanisms. Understanding and addressing drug resistance is crucial for improving long-term outcomes and achieving durable responses in cancer therapy [52].

Side effects and the management of these effects

While protein-based therapies generally have a more targeted action compared to traditional chemotherapies, they can still elicit side effects, which can vary from mild to severe. For instance, monoclonal antibodies can trigger immune-related reactions, ranging from mild skin rashes to severe infusion reactions [53]. Immune checkpoint inhibitors might lead to immune-related adverse events (irAEs), where the immune system attacks normal organs, resulting in conditions like colitis, hepatitis, or endocrinopathies. The management of these side effects involves a multidisciplinary approach, including dose adjustments, symptomatic treatments, or the use of corticosteroids and other immunosuppressive agents for severe irAEs [54]. Early detection and appropriate management of side effects are imperative to optimize patient outcomes and ensure the continuation of potentially life-saving therapies. Patient education on potential side effects and when to seek medical attention is also a crucial component of the management strategy, enabling prompt intervention and minimizing the risk of severe complications [55].





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FUTURE PERSPECTIVES

Emerging Trends in Protein-Based Therapies for Cancer

Recent trends in protein-based therapies involve the development of multi-specific antibodies, capable of engaging multiple targets simultaneously, enhancing therapeutic efficacy and overcoming resistance. Additionally, the integration of proteomics and genomics data is advancing the identification of novel targets for therapy, facilitating the development of highly specific treatments tailored to individual tumour profiles [56].

Potential for Personalized Medicine and Combination Therapies

The potential for personalized medicine in protein-based therapies is significant, with biomarker-driven strategies enabling tailored treatments that optimize efficacy and minimize toxicity. Combination therapies, pairing protein-based agents with other treatments, are being explored to address the complexity of cancer signalling networks, reduce resistance, and achieve synergistic therapeutic effects [57,58].

Innovations in Protein Engineering and Drug Delivery Systems

Protein engineering is revolutionizing therapy by enhancing the specificity, stability, and efficacy of protein-based drugs. Innovations include the design of bispecific or multi specific antibodies and the optimization of effector functions. In drug delivery, novel strategies like nanoparticle carriers and targeted delivery systems are being developed to improve the bioavailability and targeting of protein-based therapeutics, maximizing their therapeutic potential while reducing side effects [59-60].

CONCLUSION

Protein based therapies in oncology have marked a significant milestone in the evolution of cancer treatment. They offer targeted, effective, and personalized therapeutic options, distinguishing themselves from traditional chemotherapies and radiation. The ability to specifically target cancer cells while sparing normal tissues has led to improved outcomes and quality of life for patients. Despite the challenges of drug resistance and side effects, ongoing research, clinical trials, and technological advancements continue to enhance the efficacy and scope of these therapies. The integration of protein-based therapies with other treatment modalities, the exploration of novel targets through advanced biotechnological techniques, and the commitment to personalized medicine are paving the way for a future where cancer treatment is more effective, less toxic, and tailored to the individual's specific cancer profile. The continued innovation and application of protein-based therapies hold great promise for transforming the landscape of cancer treatment and improving patient survival and well-being.

REFERENCES

1. Serna N, Sanchez Garcia L, Unzueta U, Diaz R, Vazquez E, Mangues R & Villaverde A. Protein-based therapeutic killing for cancer therapies. Trends in biotechnology 2018; 36(3): 318-335.
2. Kintzing JR, Interrante MV & Cochran JR. Emerging strategies for developing next-generation protein therapeutics for cancer treatment. Trends in pharmacological sciences 2016; 37(12): 993-1008.
3. Liu X, Wu F, Ji Y & Yin L. Recent advances in anti-cancer protein/peptide delivery. Bioconjugate chemistry 2018; 30(2): 305-24.
4. Zhu X, Anquillare EL, Farokhzad OC & Shi J. Polymer and protein-based nanotechnologies for cancer theranostics. Cancer Theranostics 2014; 1: 419-36.
5. French LE & Tschopp J. Protein-based therapeutic approaches targeting death receptors. Cell Death & Differentiation 2003; 10(1): 117-23.
6. Kintzing JR, Interrante MV & Cochran JR. Emerging strategies for developing next-generation protein therapeutics for cancer treatment. Trends in pharmacological sciences 2016; 37(12): 993-1008.



**Mallikarjuna Gandla and Niranjan Babu Mudduluru**

7. Zhang Q, Zhang J, Song J, Liu Y, Ren X & Zhao Y. Protein-based nanomedicine for therapeutic benefits of cancer. *ACS nano* 2021; 15(5): 8001-38.
8. Alghamdi MA, Fallica AN, Virzi N, Kesharwani P, Pittala V & Greish K. The promise of nanotechnology in personalized medicine. *Journal of personalized medicine* 2022; 12(5): 673.
9. Serna N, Sanchez-Garcia L, Unzueta U, Diaz R, Vazquez E, Mangues R & Villaverde A. Protein based therapeutic killing for cancer therapies. *Trends in biotechnology* 2018; 36(3): 318-35.
10. Farjadian F, Ghasemi A, Gohari O, Roointan A, Karimi M & Hamblin MR. Nanopharmaceuticals and nanomedicines currently on the market: challenges and opportunities. *Nanomedicine* 2019;14(1): 93-126.
11. Koff WC, Rappuoli R & Plotkin SA. Historical advances in structural and molecular biology and how they impacted vaccine development. *Journal of Molecular Biology* 2023; 435(13): 168113.
12. Doevendans E & Schellekens H. Immunogenicity of innovative and biosimilar monoclonal antibodies. *Antibodies* 2019; 8(1): 21.
13. Sharkey RM & Goldenberg DM. Targeted therapy of cancer: new prospects for antibodies and immunoconjugates. *CA: A Cancer Journal for Clinicians* 2006; 56(4): 226-43.
14. Mojtahedi H. Monoclonal antibodies as therapeutic agents: advances and challenges. 2008; 1: 67-71.
15. Woodward IR & Fromen CA. Recent Developments in Aerosol Pulmonary Drug Delivery: New Technologies, New Cargos, and New Targets. *Annual Review of Biomedical Engineering* 2024; 29: 26.
16. Dias JN. Clinical and Immunological Characterization of Naturally Occurring Canine Lymphoma: Development and Application of Engineered Recombinant Antibodies for Diagnosis and Treatment (Doctoral dissertation, Universidade de Lisboa (Portugal)).
17. Dimitrov DS. Therapeutic proteins. *Therapeutic Proteins: Methods and Protocols* 2012; 1-26.
18. Tycko J, Myer VE & Hsu PD. Methods for optimizing CRISPR-Cas9 genome editing specificity. *Molecular cell* 2016;63(3): 355-70.
19. Iyer DN, Schimmer AD & Chang H. Applying CRISPR-Cas9 screens to dissect hematological malignancies. *Blood Advances* 2023;7(10): 2252-70.
20. Yadav A, Singh S, Sohi H & Dang S. Advances in delivery of chemotherapeutic agents for cancer treatment. *AAPS Pharm Sci Tech* 2022; 23: 1-4.
21. Fernández M, Javid F & Chudasama V. Advances in targeting the folate receptor in the treatment/imaging of cancers. *Chemical science* 2018; 9(4): 790-810.
22. Chehelgerdi M, Allela OQ, Pecho RD, Jayasankar N, Rao DP, Thamaraiyani T, Vasanthan M, Viktor P, Lakshmaiyi N & Saadh MJ. Progressing nanotechnology to improve targeted cancer treatment: overcoming hurdles in its clinical implementation. *Molecular cancer* 2023; 22(1): 169.
23. Tonry C, Finn S, Armstrong J & Pennington SR. Clinical proteomics for prostate cancer: understanding prostate cancer pathology and protein biomarkers for improved disease management. *Clinical Proteomics* 2020; 17: 1-31.
24. Barfield C & Calfee JE. *Biotechnology and the patent system*. American Enterprise Institute: Washington, DC, 2007; 87.
25. Baumer N, Berdel WE & Baumer S. Immunoprotein-mediated siRNA delivery. *Molecular Pharmaceutics* 2017;14(5): 1339-51.
26. Nadal L. Isolation and validation of novel monoclonal antibodies targeting the tumor microenvironment for the selective delivery of cytokines payloads. 2021.
27. Marrocco I, Romaniello D & Yarden Y. Cancer immunotherapy: the dawn of antibody cocktails. *Human Monoclonal Antibodies: Methods and Protocols* 2019; 11-51.
28. Le I, Dhandayuthapani S, Chacon J, Eiring AM & Gadad SS. Harnessing the immune system with cancer vaccines: From prevention to therapeutics. *Vaccines* 2022;10(5): 816.
29. Wong KK, Li WA, Mooney DJ & Dranoff G. Advances in therapeutic cancer vaccines. *Advances in immunology* 2016; 130: 191-249.
30. DeLucia DC & Lee JK. Development of cancer immunotherapies. In *Cancer Immunotherapies: Solid Tumors and Hematologic Malignancies* Cham: Springer International Publishing 2022; 1-48.
31. Demaria O, Cornen S, Daeron M, Morel Y, Medzhitov R & Vivier E. Harnessing innate immunity in cancer therapy. *Nature* 2019; 574(7776): 45-56.



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32. Keshavarz M, Solaymani Mohammadi F, Miri SM & Ghaemi A. Oncolytic paramyxoviruses induced autophagy; a prudent weapon for cancer therapy. *Journal of biomedical science* 2019; 26(1): 48.
33. Kareppa MS. *Immuno-Oncology Agents-A New Era of Cancer Therapy*.
34. Raghani NR, Chorawala MR, Mahadik M, Patel RB, Prajapati BG & Parekh PS. Revolutionizing cancer treatment: comprehensive insights into immunotherapeutic strategies. *Medical Oncology* 2024; 41(2): 51.
35. Abdolvahab MH, Darvishi B, Zarei M, Majidzadeh AK & Farahmand L. Interferons: Role in cancer therapy. *Immunotherapy* 2020;12(11): 833-55.
36. Ryff JC & Pestka S. Interferons and interleukins. In *Pharmaceutical biotechnology: fundamentals and applications*, New York, NY: Springer 2013; 413-437.
37. Grande C, Firvida JL, Navas V & Casal J. Interleukin-2 for the treatment of solid tumors other than melanoma and renal cell carcinoma. *Anti-cancer drugs* 2006;17(1): 1-2.
38. Sitia L, Sevieri M, Signati L, Bonizzi A, Chesì A, Mainini F, Corsi F & Mazzucchelli S. HER-2-targeted nanoparticles for breast cancer diagnosis and treatment. *Cancers* 2022;14(10): 2424.
39. Kang J. *Development and Characterization of Monoclonal Antibodies against Pseudomonas aeruginosa* (Doctoral dissertation, West Virginia University).
40. Ajina A & Maher J. Synergistic combination of oncolytic virotherapy with CAR T-cell therapy. *Progress in Molecular Biology and Translational Science* 2019;164: 217-92.
41. Hager S, Fittler FJ, Wagner E & Bros M. Nucleic acid-based approaches for tumor therapy. *Cells* 2020; 9(9): 2061.
42. Nair A, Chauhan P, Saha B & Kubatzky KF. Conceptual evolution of cell signaling. *International journal of molecular sciences* 2019; 20(13): 3292.
43. Lim B, Greer Y, Lipkowitz S & Takebe N. Novel apoptosis-inducing agents for the treatment of cancer, a new arsenal in the toolbox. *Cancers* 2019; 11(8): 1087.
44. Gun SY, Lee SW, Sieow JL & Wong SC. Targeting immune cells for cancer therapy. *Redox biology* 2019; 25: 101174.
45. Wang JJ, Lei KF & Han FJ. Tumor microenvironment: recent advances in various cancer treatments. *European Review for Medical & Pharmacological Sciences* 2018; 22(12).
46. Reslan L. *Comparison of the cytotoxic mechanisms of anti-CD20 monoclonal antibodies Rituximab and GA101 in Chronic Lymphocytic Leukemia* (Doctoral dissertation, Université Claude Bernard-Lyon I).
47. Webster RM. Combination therapies in oncology. *Nature reviews. Drug discovery* 2016; 15(2): 81.
48. Barbee MS, Ogunniyi A, Horvat TZ & Dang TO. Current status and future directions of the immune checkpoint inhibitors ipilimumab, pembrolizumab, and nivolumab in oncology. *Annals of Pharmacotherapy* 2015; 49(8): 907-37.
49. Viardot A, Wais V, Sala E & Koerper S. Chimeric antigen receptor (CAR) T-cell therapy as a treatment option for patients with B-cell lymphomas: perspectives on the therapeutic potential of *Axicabtagene ciloleucel*. *Cancer Management and Research* 2019; 25: 2393-404.
50. Healy FM, Prior IA & MacEwan DJ. The importance of Ras in drug resistance in cancer. *British Journal of Pharmacology*. 2022 Jun;179(12):2844-67.
51. Gaibar M, Beltrán L, Romero-Lorca A, Fernandez-Santander A, Novillo A. Somatic mutations in HER2 and implications for current treatment paradigms in HER2-positive breast cancer. *Journal of Oncology* 2020; 10.
52. Wu M, Huang Q, Xie Y, Wu X, Ma H, Zhang Y & Xia Y. Improvement of the anticancer efficacy of PD-1/PD-L1 blockade via combination therapy and PD-L1 regulation. *Journal of hematology & oncology* 2022; 15(1): 24.
53. Hansel TT, Kropshofer H, Singer T, Mitchell JA & George AJ. The safety and side effects of monoclonal antibodies. *Nature reviews Drug discovery* 2019; 9(4): 325-38.
54. Schneider BJ, Naidoo J, Santomaso BD, Lacchetti C, Adkins S, Anadkat M, Atkins MB, Brassil KJ, Caterino JM, Chau I & Davies MJ. Management of immune-related adverse events in patients treated with immune checkpoint inhibitor therapy: ASCO guideline update. *Journal of clinical oncology* 2021; 39(36): 4073-126.
55. Langer Gould A, Moses HH & Murray TJ. Strategies for managing the side effects of treatments for multiple sclerosis. *Neurology* 2004; 63(5): S35-41.
56. Luo C, Wang P, He S, Zhu J, Shi Y & Wang J. Progress and prospect of immunotherapy for triple-negative breast cancer. *Frontiers in Oncology* 2022;12: 919072.





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57. Li H, Luo Q, Zhang H, Ma X, Gu Z, Gong Q & Luo K. Nanomedicine embraces cancer radio-immunotherapy: mechanism, design, recent advances, and clinical translation. *Chemical Society Reviews* 2023; 52(1): 47-96.
58. Grech G, Zhan X, Yoo BC, Bubnov R, Hagan S, Danesi R, Vittadini G & Desiderio DM. EPMA position paper in cancer: current overview and future perspectives. *EPMA Journal* 2015; 6: 1-31.
59. Rondon A, Mahri S, Morales Yanez F, Dumoulin M & Vanbever R. Protein engineering strategies for improved pharmacokinetics. *Advanced Functional Materials* 2021; 31(44): 2101633.
60. Rosenkranz AA & Slastnikova TA. Prospects of Using Protein Engineering for Selective Drug Delivery into a Specific Compartment of Target Cells. *Pharmaceutics* 2023; 15(3): 987.

Table 1: Comparison Between Protein-Based Therapies and Traditional Cancer Treatments

Aspect	Protein-Based Therapies	Traditional Cancer Treatments
Mechanism	Target specific molecular pathways in cancer cells.	Generally, target rapidly dividing cells, affecting both cancerous and healthy cells.
Specificity	High specificity to cancer cells or the tumour microenvironment.	Low specificity, affecting a broad range of cells.
Side Effects	Generally fewer and less severe due to targeted action.	Often significant, due to non-specific action on healthy cells.
Patient Impact	Improved quality of life, potential for personalized treatment.	Broad systemic effects, significant impact on quality of life.

Table 2: Types of Protein-Based Therapies

S. No	Type of Therapy	Definition	Mechanism of Action	Examples
1	Monoclonal Antibodies	Engineered immunoproteins that bind to specific antigens on cancer cells.	Induce immune response, block growth factor receptors, promote cell lysis.	Trastuzumab, Rituximab
2	Cancer Vaccines	Stimulate the immune system to recognize and attack cancer cells.	Induce an immune response against cancer-specific antigens.	Sipuleucel-T, HPV vaccine
3	Oncolytic Virus Therapy	Uses modified viruses that selectively infect and destroy cancer cells.	Infect and lyse cancer cells, induce immune response against tumors	Talimogene laherparepvec (T-VEC)
4	Immune Checkpoint Inhibitors	Block proteins that cancer cells use to avoid immune detection, enhancing the immune system's response.	Disrupt interactions between cancer cells and immune checkpoints.	Nivolumab (PD-1 inhibitor), Ipilimumab
5	Cytokine Therapy	Uses signaling proteins to modulate the immune system against cancer.	Promote activation and proliferation of immune cells.	Interferon-alpha, Interleukin-2

Table 3: Clinical Applications and Case Studies

Therapy	Cancer Type	Description	Outcomes/Benefits
Trastuzumab (Herceptin)	HER2-positive breast cancer	Monoclonal antibody targeting HER2 receptor.	Improved survival rates, reduced recurrence risk.
Rituximab (Rituxan)	Non-Hodgkin lymphoma (NHL)	Monoclonal antibody targeting CD20 antigen on B cells.	Significantly improved survival rates in NHL and CLL.





Applying the Double Formable Transform to Deal with a Various Boundary Value Problems: The Telegraph Equations and the Klein-Gordon Equations

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ABSTRACT

Partial differential equations can be solved using many different kinds of methods. Among these, the integral transform proves to be an extremely efficient method for solving partial differential equations. Thus, a double-Formable transform shall be used to solve boundary value problems in this paper. Here, we'll solve Klein-Gordon equations, homogeneous and non-homogeneous telegraph equations, and partial differential equations of first and second order etc.

Keywords: Formable Transform, Double Formable Transform, Partial Differential equation, Telegraph equation, Klein-Gordon equation, Linear partial differential equation.

2010 AMS Classification: 35A22, 44A35, 44A05, 44A10, 42B10.

INTRODUCTION

Differential equations are an important topic in mathematics that are used to model various medical difficulties as well as several physical and engineering research problems. Thus, the ability to solve differential equations is vital. Several researchers have developed an abundance of methods that are applied to solve differential equations. Among those, using the integral transform to solve differential equations is the most effective method. The performance and utility of the integral transform approach have been demonstrated in the solution of fractional differential equations,





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integro-differential equations, ordinary and partial differential equations, etc. The integral remodel was introduced by the French scientist and man of science, P.S. Marquis de Laplace, in 1780 [5].

Definition: The Laplace transform of a function $f(t)$, defined for all real numbers $t \geq 0$, is the function $F(s)$, which is a unilateral transform defined by $F(s) = \int_0^\infty f(t)e^{-st} dt$ where s is a complex number variable $s = \sigma + i\omega$ with real numbers σ and ω .

Different kinds of integral transformations include the Soham Transform[11], Kushare Transform[12], Fourier transformation[5], Natural transformation[14], and new general integral transform[4], among others. Many fields, especially engineering, physics, applied mathematics, and most other sciences, may profit from these kinds of changes.

USEFUL DEFINITIONS AND RESULTS

The Formable Transform[FT] is a valuable tool for solving ordinary and partial differential equations, and Saadeh, R.Z. and Ghazal, B.f. introduce it in 2021. The transformation is defined as follows by them. [9]

Definition 1:The Formable Transform of the continuous function $h(t)$ on the interval $[0, \infty)$ is a new integral transform that is defined as below.

$$R[h(t)] = B(s, u) = \frac{s}{u} \int_0^\infty e^{-\frac{s}{u}t} h(t) dt.$$

Definition 2: The inverse FT is defined as $R^{-1}[R[h(t)]] = \frac{1}{2\pi i} \int_{c-i\infty}^{c+i\infty} e^{(s/u)t} B(s, u) ds = h(t)$.

The Formable transform of some functions is collected in the table as below Two-variable integral transforms are required after a single-variable transform in order to solve partial and integral differential equations. In applied mathematics and mathematical physics, a double integral transform is needed to solve starting and boundary value problems. Many double integral transforms have been developed and introduced, such as the Laplace-Sumudu Transform [3, 13], the double Laplace transform [5], the double Natural transform [1], the double Aboodh Transform [6], the double General transform [8], the double Rangaig transform [7], and so on. In recent days, the Double Formable Transform [DFT] was developed by Bayan Ghazal et al. The following are some definitions and characteristics of double FT [2, 10].

Definition 3: Let $g(t_1, t_2)$ be a continuous function of two variables, $t_1 > 0$ and $t_2 > 0$. Then, the double Formable transform (DFT) of a function $g(t_1, t_2)$ is defined as

$$R_{t_1} R_{t_2} [g(t_1, t_2)] = \frac{s_2 s_1}{u_2 u_1} \int_0^\infty \int_0^\infty e^{-\left(\frac{s_1}{u_1}t_1 + \frac{s_2}{u_2}t_2\right)} g(t_1, t_2) dt_1 dt_2$$

$$R_{t_1} R_{t_2} [g(t_1, t_2)] = H(s_1, u_1, s_2, u_2) = s_1 s_2 \int_0^\infty \int_0^\infty e^{-(s_1 t_1 + s_2 t_2)} g(u_1 t_1, u_2 t_2) dt_1 dt_2$$

The inverse of DFT is given by

$$R_{t_1}^{-1} R_{t_2}^{-1} [R_{t_1} R_{t_2} g(t_1, t_2)] = \frac{1}{2\pi i} \int_{c-i\infty}^{c+i\infty} \frac{1}{2\pi i} \int_{d-i\infty}^{d+i\infty} \frac{1}{s_1 s_2} e^{\left(\frac{s_2}{u_2}t_2 + \frac{s_1}{u_1}t_1\right)} H(s_1, u_1, s_2, u_2) ds_2 ds_1 = g(t_1, t_2).$$

The double Formable transform of some functions collected in the table as below[2,10]

APPLICATION OF DOUBLE FORMABLE TRANSFORM

Here, we utilize DFT to solve a variety of boundary value problems.





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Application To Telegraph equation

In this subsection we solve homogeneous, non-homogeneous and general form of telegraph equations.

Method To Solve: The generalize solution for a general Telegraph equation

$$g_{t_1 t_2}(t_1, t_2) + ag_{t_2}(t_1, t_2) + bg(t_1, t_2) = c^2 g_{t_1 t_2}(t_1, t_1) \dots\dots(1)$$

with boundary conditions $g(0, t_2) = f_1(t_2), g_{t_1}(0, t_2) = g_1(t_2)$ (2)

with initial conditions $g(t_1, 0) = f_2(t_1), g_{t_2}(t_1, 0) = g_2(t_1)$(3)

Solution: Taking DFT of the equation (1) we get

$$\begin{aligned} \frac{s_2^2}{u_2^2} R_{t_1} R_{t_2} [g(t_1, t_2)] - \frac{s_2^2}{u_2^2} R[g(t_1, 0)] - \frac{s_2}{u_2} R[g_{t_2}(t_1, 0)] + a \frac{s_2}{u_2} R_{t_1} R_{t_2} [g(t_1, t_2)] - a \frac{s_2}{u_2} R[g(t_1, 0)] \\ + b R_{t_1} R_{t_2} [g(t_1, t_2)] = c^2 \frac{s_1^2}{u_1^2} R_{t_1} R_{t_2} [g(t_1, t_2)] - c^2 \frac{s_1^2}{u_1^2} R[g(0, t_2)] - c^2 \frac{s_1}{u_1} R[g_{t_1}(0, t_2)] \\ \left(\frac{s_2^2}{u_2^2} + a \frac{s_2}{u_2} + b - c^2 \frac{s_1^2}{u_1^2}\right) R_{t_1} R_{t_2} [g(t_1, t_2)] - \left(\frac{s_2^2}{u_2^2} + a \frac{s_2}{u_2}\right) R[g(t_1, 0)] - \frac{s_2}{u_2} R[g_{t_2}(t_1, 0)] \\ = -c^2 \frac{s_1^2}{u_1^2} R[g(0, t_2)] - c^2 \frac{s_1}{u_1} R[g_{t_1}(0, t_2)] \\ \left(\frac{s_2^2}{u_2^2} + a \frac{s_2}{u_2} + b - c^2 \frac{s_1^2}{u_1^2}\right) R_{t_1} R_{t_2} [g(t_1, t_2)] \\ = \left(\frac{s_2^2}{u_2^2} + a \frac{s_2}{u_2}\right) R[g(t_1, 0)] + \frac{s_2}{u_2} R[g_{t_2}(t_1, 0)] - c^2 \frac{s_1^2}{u_1^2} R[g(0, t_2)] - c^2 \frac{s_1}{u_1} R[g_{t_1}(0, t_2)] \dots\dots(4) \end{aligned}$$

Taking FT of equation (2) and (3), we get

$$R_{t_2} [g(0, t_2)] = R_{t_2} [f_1(t_2)] = F_1(s_2, u_2) \text{ and } R_{t_2} [g_{t_1}(0, t_2)] = R_{t_2} [g_1(t_2)] = G_1(s_2, u_2) \dots(5)$$

$$R_{t_1} [g(t_1, 0)] = R_{t_1} [f_2(t_1)] = F_2(s_2, u_1) \text{ and } R_{t_1} [g_{t_2}(t_1, 0)] = R_{t_1} [g_2(t_1)] = G_2(s_2, u_1) \dots(6)$$

Substitute equation (5) and (6) in equation (4), we get

$$\left(\frac{s_2^2}{u_2^2} + a \frac{s_2}{u_2} + b - c^2 \frac{s_1^2}{u_1^2}\right) R_{t_1} R_{t_2} [g(t_1, t_2)] = \left(\frac{s_2^2}{u_2^2} + a \frac{s_2}{u_2}\right) F_2(s_1, u_1) + \frac{s_2}{u_2} G_2(s_1, u_1) G_1(s_2, u_2) - c^2 \frac{s_1^2}{u_1^2} F_1(s_2, u_2) - c^2 \frac{s_1}{u_1}$$

after simplification, we get

$$\begin{aligned} R_{t_1} R_{t_2} [g(t_1, t_2)] &= \frac{\left(\frac{s_2^2}{u_2^2} + a \frac{s_2}{u_2}\right) F_2(s_1, u_1) + \frac{s_2}{u_2} G_2(s_1, u_1) - c^2 \frac{s_1^2}{u_1^2} F_1(s_2, u_2) - c^2 \frac{s_1}{u_1} G_1(s_2, u_2)}{\left(\frac{s_2^2}{u_2^2} + a \frac{s_2}{u_2} + b - c^2 \frac{s_1^2}{u_1^2}\right)} \\ &= H(s_1, u_1, s_2, u_2) \dots\dots\dots(Say) \end{aligned}$$

Taking inverse DFT of above equation, we get required solution general telegraph equation $g(t_1, t_2) = R_{t_1}^{-1} R_{t_2}^{-1} [H(s_1, u_1, s_2, u_2)] = K(t_1, t_2)$

here, we assume that the double inverse Formable transform is exist.

Example 1:Show that the solution of the homogeneous telegraph equation





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$$g_{t_1 t_1}(t_1, t_2) - g_{t_2 t_2}(t_1, t_2) - g_{t_2}(t_1, t_2) + g(t_1, t_2) = 0 \quad \dots\dots\dots(7)$$

with boundary conditions $g(0, t_2) = e^{-2t_2}, g_{t_1}(0, t_2) = e^{-2t_2} \quad \dots\dots\dots(8)$

with initial conditions $g(t_1, 0) = e^{t_1}, g_{t_2}(t_1, 0) = -2e^{t_1} \quad \dots\dots\dots(9)$

is $g(t_1, t_2) = e^{(t_1-2t_2)}$.

Solution: Taking DFT of the equation (7) we get

$$\frac{s_1^2}{u_1^2} R_{t_1} R_{t_2} [g(t_1, t_2)] - \frac{s_1^2}{u_1^2} R_{t_2} [g(0, t_2)] - \frac{s_1}{u_1} R_{t_2} [g_{t_2}(0, t_2)] - \frac{s_2^2}{u_2^2} R_{t_1} R_{t_2} [g(t_1, t_2)] - \frac{s_2^2}{u_2^2} R_{t_1} [g(t_1, 0)] + \frac{s_2}{u_2} R_{t_1} [g_{t_2}(t_1, 0)] - \frac{s_2}{u_2} R_{t_1} R_{t_2} [g(t_1, t_2)] + \frac{s_2}{u_2} R_{t_1} [g(t_1, 0)] + R_{t_1} R_{t_2} [g(t_1, t_2)] = 0 \quad \dots (10)$$

Taking FT of equation (8) and (9), we get

$$R_{t_2} [g(0, t_2)] = R_{t_2} [e^{-2t_2}] = \frac{s_2}{u_2 + s_2}, \quad R_{t_2} [g_{t_1}(0, t_2)] = R_{t_2} [e^{-2t_2}] = \frac{s_2}{2u_2 + s_2} \dots \dots (11)$$

$$R_{t_1} [g(t_1, 0)] = R_{t_1} [e^{t_1}] = \frac{s_1}{s_1 - u_1}, \quad R_{t_1} [g_{t_2}(t_1, 0)] = R_{t_1} [-2e^{t_1}] = \frac{-2s_1}{s_1 - u_1} \dots \dots (12)$$

Substitute equation (11) to (12) in equation (10) and after simplification, we get

$$\left(\frac{s_1^2 u_2^2 - s_2^2 u_1^2 - s_2 u_1^2 u_2 + u_1^2 u_2^2}{u_1^2 u_2^2} \right) R_{t_1} R_{t_2} [g(t_1, t_2)] = \left(\frac{s_1^2 u_2^2 - s_2^2 u_1^2 - s_2 u_1^2 u_2 + u_1^2 u_2^2}{u_1^2 u_2^2} \right) \left[\frac{s_1 s_2}{(s_1 + 2u_2)(s_1 - u_1)} \right]$$

$$R_{t_1} R_{t_2} [g(t_1, t_2)] = \left[\frac{s_1 s_2}{(s_1 + 2u_2)(s_1 - u_1)} \right]$$

Taking inverse DFT, we get $g(t_1, t_2) = e^{(t_1-2t_2)}$ which is required solution.

Example 2: Show that the solution of the non-homogeneous telegraph equation

$$g_{t_1 t_1}(t_1, t_2) - g_{t_2 t_2}(t_1, t_2) - g_{t_2}(t_1, t_2) - g(t_1, t_2) = -2e^{(t_1+t_2)} \dots\dots\dots(13)$$

with boundary conditions $g(0, t_2) = e^{t_2}, g_{t_1}(0, t_2) = e^{t_2} \dots\dots\dots(14)$

with initial conditions $g(t_1, 0) = e^{t_1}, g_{t_2}(t_1, 0) = -2e^{t_1} \dots\dots\dots(15)$

is $g(t_1, t_2) = e^{(t_1+t_2)}$.

Solution: Taking DFT of the equation (13) we get

$$\frac{s_1^2}{u_1^2} R_{t_1} R_{t_2} [g(t_1, t_2)] - \frac{s_1^2}{u_1^2} R_{t_2} [g(0, t_2)] - \frac{s_1}{u_1} R_{t_2} [g_{t_2}(0, t_2)] - \frac{s_2^2}{u_2^2} R_{t_1} R_{t_2} [g(t_1, t_2)] - \frac{s_2^2}{u_2^2} R_{t_1} [g(t_1, 0)] + \frac{s_2}{u_2} R_{t_1} [g_{t_2}(t_1, 0)] - \frac{s_2}{u_2} R_{t_1} R_{t_2} [g(t_1, t_2)] + \frac{s_2}{u_2} R_{t_1} [g(t_1, 0)] + R_{t_1} R_{t_2} [g(t_1, t_2)] = \frac{-2s_1 s_2}{(s_1 - u_1)(s_2 - u_2)} \dots (16)$$

Taking FT of equation (14) and (15), we get

$$R_{t_2} [g(0, t_2)] = R_{t_2} [e^{-2t_2}] = \frac{s_2}{s_2 - u_2}, \text{ and } R_{t_2} [g_{t_1}(0, t_2)] = R_{t_2} [e^{-2t_2}] = \frac{s_2}{s_2 - u_2} \dots \dots \dots (17)$$

$$R_{t_1} [g(t_1, 0)] = R_{t_1} [e^{t_1}] = \frac{s_1}{s_1 - u_1}, \text{ and } R_{t_1} [g_{t_2}(t_1, 0)] = R_{t_1} [-2e^{t_1}] = \frac{s_1}{s_1 - u_1} \dots \dots \dots (18)$$

Substitute equation (17) to (18) in equation (16) and after simplification, we get

$$\left(\frac{s_1^2 u_2^2 - s_2^2 u_1^2 - s_2 u_1^2 u_2 - u_1^2 u_2^2}{u_1^2 u_2^2} \right) R_{t_1} R_{t_2} [g(t_1, t_2)] = \left(\frac{s_1^2 u_2^2 - s_2^2 u_1^2 - s_2 u_1^2 u_2 - u_1^2 u_2^2}{u_1^2 u_2^2} \right) \left[\frac{s_1 s_2}{(s_1 - u_1)(s_2 - u_2)} \right]$$





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$$R_{t_1}R_{t_2}[g(t_1, t_2)] = \left[\frac{s_1s_2}{(s_1-u_1)(s_2-u_2)} \right]$$

Taking inverse DFT, we get $g(t_1, t_2) = e^{(t_1+t_2)}$ which is required solution.

Application To Klein Gordon equation

Method to solve: The generalize solution for a Klein Gordon equation

$$g_{t_2t_2}(t_1, t_2) - g_{t_1t_1}(t_1, t_2) + ag(t_1, t_2) = h(t_1, t_2) \dots \dots \dots (19)$$

with boundary conditions $g(t_1, 0) = f_1(t_1), g_{t_2}(t_1, 0) = f_2(t_1) \dots \dots \dots (20)$

with initial conditions $g(0, t_2) = h_1(t_2), g_{t_1}(0, t_2) = h_2(t_2) \dots \dots \dots (21)$

Solution: Taking DFT of the equation (19) we get

$$\begin{aligned} & \frac{s_2^2}{u_2^2}R_{t_1}R_{t_2}[g(t_1, t_2)] - \frac{s_2^2}{u_2^2}R[g(t_1, 0)] - \frac{s_2}{u_2}R[g_{t_2}(t_1, 0)] - \frac{s_1^2}{u_1^2}R_{t_1}R_{t_2}[g(t_1, t_2)] + \frac{s_1^2}{u_1^2}R[g(0, t_2)] \\ & \quad + \frac{s_1}{u_1}R[g_{t_1}(0, t_2)]aR_{t_1}R_{t_2}[g(t_1, t_2)] = R_{t_1}R_{t_2}[h(t_1, t_2)] \\ & \left(\frac{s_2^2}{u_2^2} - \frac{s_1^2}{u_1^2} + a \right) R_{t_1}R_{t_2}[g(t_1, t_2)] - \frac{s_2^2}{u_2^2}R[g(t_1, 0)] + \frac{s_1^2}{u_1^2}R[g(0, t_2)] - \frac{s_2}{u_2}R[g_{t_2}(t_1, 0)] \\ & \quad + \frac{s_1}{u_1}R[g_{t_1}(0, t_2)] = R_{t_1}R_{t_2}[h(t_1, t_2)] \\ & \left(\frac{s_2^2}{u_2^2} - \frac{s_1^2}{u_1^2} + a \right) R_{t_1}R_{t_2}[g(t_1, t_2)] = R_{t_1}R_{t_2}[h(t_1, t_2)] + \frac{s_2^2}{u_2^2}R[g(t_1, 0)] - \frac{s_1^2}{u_1^2}R[g(0, t_2)] \\ & \quad + \frac{s_2}{u_2}R[g_{t_2}(t_1, 0)] - \frac{s_1}{u_1}R[g_{t_1}(0, t_2)] \dots (22) \end{aligned}$$

Taking FT of equation (20) and (21), we get

$$R_{t_2}[g(0, t_2)] = R_{t_2}[h_1(t_2)] = H_1(s_2, u_2), \text{ and } R_{t_2}[g_{t_1}(0, t_2)] = R_{t_2}[h_2(t_2)] = H_2(s_2, u_2) \dots (23)$$

$$R_{t_1}[g(t_1, 0)] = R_{t_1}[f_1(t_1)] = F_1(s_2, u_1), \text{ and } R_{t_1}[g_{t_2}(t_1, 0)] = R_{t_1}[f_2(t_1)] = F_2(s_2, u_1) \dots (24)$$

Substitute equation (23) to (24) in equation (22), we get

$$R_{t_1}R_{t_2}[g(t_1, t_2)] = H[(s_1, u_1, s_2, u_2)] + \frac{s_2^2}{u_2^2}F_1(s_2, u_1) - \frac{s_1^2}{u_1^2}H_1(s_2, u_2) + \frac{s_2}{u_2}F_2(s_2, u_1) - \frac{s_1}{u_1}H_2(s_2, u_2)$$

after simplification, we get

$$\begin{aligned} R_{t_1}R_{t_2}[g(t_1, t_2)] &= \frac{H(s_1, u_1, s_2, u_2) + \frac{s_2^2}{u_2^2}F_1(s_2, u_1) - \frac{s_1^2}{u_1^2}H_1(s_2, u_2) + \frac{s_2}{u_2}F_2(s_2, u_1) - \frac{s_1}{u_1}H_2(s_2, u_2)}{\left(\frac{s_2^2}{u_2^2} - \frac{s_1^2}{u_1^2} + a \right)} \\ &= K(s_1, u_1, s_2, u_2) \dots \dots \dots (Say) \end{aligned}$$

Taking inverse DFT of above equation, we get required solution general Klein Gordon equation.

$$g(t_1, t_2) = R_{t_1}^{-1}R_{t_2}^{-1}[K(s_1, u_1, s_2, u_2)] = k(t_1, t_2)$$

here, we assume that the double inverse Formable transform is exist.

Example 3: Show that the solution of Klein Gordon equation





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$$g_{t_2 t_2}(t_1, t_2) - g_{t_1 t_1}(t_1, t_2) - g(t_1, t_2) = 0 \dots\dots\dots(25)$$

with boundary conditions $g(0, t_2) = 0, g_{t_1}(0, t_2) = t_2 \dots\dots\dots(26)$

with initial conditions $g(t_1, 0) = 0, g_{t_2}(t_1, 0) = \text{sint}_1 \dots\dots\dots (27)$

is $g(t_1, t_2) = t_2 \text{sint}_1$

Solution: Taking DFT of the equation (25), we get

$$\begin{aligned} & \left(\frac{s_2^2}{u_2^2}\right)R_{t_1}R_{t_2}[g(t_1, t_2)] - \frac{s_2^2}{u_2^2}R[g(t_1, 0)] - \frac{s_2}{u_2}R[g_{t_2}(t_1, 0)] - \frac{s_1^2}{u_1^2}R_{t_1}R_{t_2}[g(t_1, t_2)] + \frac{s_1^2}{u_1^2}R[g(0, t_2)] \\ & + \frac{s_1}{u_1}R[g_{t_1}(0, t_2)] - R_{t_1}R_{t_2}[g(t_1, t_2)] = 0 \\ & \left(\frac{s_2^2}{u_2^2} - \frac{s_1^2}{u_1^2} - 1\right)R_{t_1}R_{t_2}[g(t_1, t_2)] = \frac{s_2^2}{u_2^2}R[g(t_1, 0)] + \frac{s_2}{u_2}R[g_{t_2}(t_1, 0)] - \frac{s_1^2}{u_1^2}R[g(0, t_2)] - \frac{s_1}{u_1}R[g_{t_1}(0, t_2)] \dots (28) \end{aligned}$$

Taking FT of equation (26) and (27) and after simplification, we get

$$R_{t_2}[g(0, t_2)] = 0, \text{ and } R_{t_2}[g_{t_1}(0, t_2)] = R_{t_2}[t_2] = \frac{u_2}{s_2} \dots\dots\dots (29)$$

$$R_{t_1}[g(t_1, 0)] = 0, \text{ and } R_{t_1}[g_{t_2}(t_1, 0)] = R_{t_1}[\text{sint}_1] = \frac{s_1 u_1}{s_1^2 + u_1^2} \dots\dots (30)$$

put (29) and (30) in equation (28), and simplify

$$\begin{aligned} & \left(\frac{s_1^2 u_1^2 - s_2^2 u_2^2 - u_1^2 u_2^2}{u_1^2 u_2^2}\right)R_{t_1}R_{t_2}[g(t_1, t_2)] = \left(\frac{s_1^2 u_1^2 - s_2^2 u_2^2 - u_1^2 u_2^2}{u_1^2 u_2^2}\right)\left[\frac{s_1 u_1 u_2}{s_2(s_1^2 + u_1^2)}\right] \\ & R_{t_1}R_{t_2}[g(t_1, t_2)] = \left(\frac{u_2}{s_2}\right)\left(\frac{s_1 u_1}{s_1^2 + u_1^2}\right) \end{aligned}$$

Taking inverse DFT, we get $g(t_1, t_2) = t_2 \text{sint}_1$ which is required solution.

Application To linear partial differential equations:

Example 4: Solve first order partial differential equation

$$\alpha g_{t_1}(t_1, t_2) + \beta g_{t_2}(t_1, t_2) + \gamma g(t_1, t_2) = h(t_1, t_2) \dots\dots\dots (31)$$

subject to the conditions $g(t_1, 0) = f_1(t_1), g(0, t_2) = f_2(t_2) \dots\dots\dots(32)$

where α, β and γ are the constant and the functions $h(t_1, t_2), f_1(t_1), f_2(t_2)$ are the continuous functions.

Proof: Applying DFT to the equation (31) we get

$$\begin{aligned} & \alpha \left[\frac{s_1}{u_1}R_{t_1}R_{t_2}[g(t_1, t_2)] - \frac{s_1}{u_1}R[g(0, t_2)]\right] + \beta \left[\frac{s_2}{u_2}R_{t_1}R_{t_2}[g(t_1, t_2)] - \frac{s_2}{u_2}R[g(t_1, 0)]\right] \\ & + \gamma R_{t_1}R_{t_2}[g(t_1, t_2)] = R_{t_1}R_{t_2}[h(t_1, t_2)] \dots\dots\dots(33) \end{aligned}$$

Applying FT to equation (32), we get

$$R_{t_1}[g(t_1, 0)] = F_1(s_1, u_1) \text{ and } R_{t_2}[g(0, t_2)] = F_2(s_2, u_2) \dots\dots\dots (34)$$

Substitute equations (34) in equation (33), and simplify we get

$$\left[\frac{\alpha s_1}{u_1} + \frac{\beta s_2}{u_2} + \gamma\right]R_{t_1}R_{t_2}[g(t_1, t_2)] = H(s_1, u_1, s_2, u_2) + \frac{\alpha s_1}{u_1}F_1(s_1, u_1) + \frac{\beta s_2}{u_2}F_2(s_2, u_2)$$





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Where $R_{t_1}R_{t_2}[h(t_1, t_2)] = H(s_1, u_1, s_2, u_2)$.

$$R_{t_1}R_{t_2}[g(t_1, t_2)] = \frac{H(s_1, u_1, s_2, u_2) + \frac{\alpha s_1}{u_1} F_1(s_1, u_1) + \frac{\beta s_2}{u_2} F_2(s_2, u_2)}{\left[\frac{\alpha s_1}{u_1} + \frac{\beta s_2}{u_2} + \gamma \right]} = K(s_1, u_1, s_2, u_2) \text{ (Say)}$$

Taking inverse DFT of above equation, we get the required solution.

Example 5 : Show that the solution of linear partial differential equation

$$g_{t_1}(t_1, t_2) + g_{t_2}(t_1, t_2) = -2e^{-(t_1+t_2)} \dots \dots \dots (35)$$

with the initial condition $g(t_1, 0) = e^{-t_1}, g(0, t_2) = e^{-t_2} \dots \dots \dots (36)$

is $g(t_1, t_2) = e^{-(t_1+t_2)}$.

Solution: Taking DFT of the equation (35) we get

$$\frac{s_1}{u_1} R_{t_1}R_{t_2}[g(t_1, t_2)] - \frac{s_1}{u_1} R[g(0, t_2)] + R_{t_1}R_{t_2}[g_{t_2}(t_1, t_2)] = \frac{-2s_1s_2}{(u_1 + s_1)(u_2 + s_2)} \dots (37)$$

Taking FT of equation (36), we get

$$R_{t_1}[g(t_1, 0)] = R[e^{-t_1}] = \frac{s_1}{u_1 + s_1} \text{ and } R_{t_2}[g(0, t_2)] = R[e^{-t_2}] = \frac{s_2}{u_2 + s_2} \dots \dots (38)$$

Substitute equations (38) in equation (37), and simplify we get

$$\left(\frac{u_1s_2 + u_2s_1}{u_1u_2} \right) R_{t_1}R_{t_2}[g(t_1, t_2)] = \left[\frac{s_1s_2}{(u_1 + s_1)(u_2 + s_2)} \right] \left(\frac{u_1s_2 + u_2s_1}{u_1u_2} \right)$$

$$R_{t_1}R_{t_2}[g(t_1, t_2)] = \left[\frac{s_1s_2}{(u_1 + s_1)(u_2 + s_2)} \right]$$

Taking inverse DFT, we get $g(t_1, t_2) = e^{-(t_1+t_2)}$ which is required solution.

CONCLUSION

This study concludes that DFT is a more efficient and easy method for solving boundary value problems. Hence it successfully applied it to the linear partial differential equation, homogeneous telegraph equation, non-homogeneous telegraph equation, and Klein-Gordon equation. Further boundary value problems may be solved in the future by using the FT and DFT transform.

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REFERENCES

1. AdemKilmac, Maryam Orman, On Double Natural Transform and its applications, J. Nonlinear Sc. Appli., 10(2017), pp. 1744-1754. URL: <http://dx.doi.org/10.22436/jnsa.010.04.36>
2. Bayan Ghazal, Rania Saadeh, Abdelilah K. Sedeeg, “Solving Partial Integro-Differential Equations via Double FT”, *Applied Computational Intelligence and Soft Computing*, vol. 2022, Article ID 6280736, 15 pages, 2022. <https://doi.org/10.1155/2022/6280736>.





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3. D. P. Patil, Solution of wave equation by double Laplace and double Sumudu transform, International Virtual Conference on Innovation in Multidisciplinary Studies-IVCIMS 2021-August 04-05, 2021.URL:<https://tinyurl.com/yc5p49dk>
4. Hossein Jafari, "A new general integral transform for solving integral equations," *Journal of Advanced Research* 32 (2021),pp.133–138. URL: A new general integral transform for solving integral equations - ScienceDirect
5. Lokenath Debnath and D. Bhatta. Integral Transform and their Application third Edition, Chapman and Hall /CRC (2014).<https://doi.org/10.1201/b17670>
6. K.S.Aboodh, et al. "Solution of Telegraph Equation by Using Double Aboodh Transform." *Elixir Appl. Math.* 110 (2017): pp. 48213-48217.URL: Elixir Journal (researchgate.net)
7. M. S. Derle, D. P. Patil and N. K. Rahane, "On Generalized Double Rangaig Integral Transform and Applications," *Stochastic Modeling, and Applications*, Vol. 26, special issue 2022. URL: <https://bit.ly/3lkaTII>
8. Meryem Meddahi, Hossein Jafari and Xiao-Jun Yang, Towards new general double integral transform and its applications to differential equations, *Math Meth Appl Sci.* 2021; pp.1–18. URL:<https://tinyurl.com/346fp46w>
9. R. Z. Saadeh, B.f.G. Ghazal, "A New Approach on Transforms,Formable Integral Transform and Its Applications", *Axioms* 2021, 10, pp. 332. DOI: <https://doi.org/10.3390/axioms10040332>
10. Saadeh, R.; Sedeeg, A.K.; Ghazal, B.; Gharib, G. Double Formable Integral Transform for Solving Heat Equations. *Symmetry* 2023, 15, 218. <https://doi.org/10.3390/sym15010218>
11. S. Khakale and D. P. Patil, "The New Integral Transform Soham transform,"*International Journal of Advances in Engineering and Management (IJAEM)*, Volume 3(10)(2021), pp: 126-132 URL: <https://ssrn.com/abstract=4128979>
12. S.Kushare, D.P. Patil and A.Takate, The New Integral Transform "KUSHARE" Transform, *International Journal of Advances in Engineering and Management (IJAEM)* Volume 3(9)(2021),pp. 1589-1592. URL: <http://dx.doi.org/10.35629/5252-030915891592>
13. Shams A. Ahmed,Tarig M. Elzaki and Abdelgabar Adam Hassan, Solution of Integral Differential Equations by New Double Integral Transform (Laplace–Sumudu Transform), *Hindawi Abstract and Applied Analysis*, Volume 2020 URL:<https://doi.org/10.1155/2020/4725150>
14. Zafar H. Khan and Wakar A. Khan, N-transform properties and application, *NUST journal of engineering*, Vol. 1, No. 1, 2008,pp-127-133.URL:<https://tinyurl.com/mrsafe59>

Table 1: Formable transform of some functions

Function	Formable transform
1	1
t^α	$\frac{u^\alpha}{s^\alpha} \Gamma(\alpha + 1), \alpha > 0$
e^{at}	$\frac{s}{s - au}$
$\sin(at)$	$\frac{asu}{s^2 + a^2u^2}$
$\cos(at)$	$\frac{s^2}{s^2 + a^2u^2}$

Table 2: Double Formable Transform of some functions

Function $g(t_1, t_2)$	Double Formable Transform [DFT]
1	1
$t_1^m t_2^n$	$(m!n!) \left(\frac{u_1}{s_1}\right)^m \left(\frac{u_2}{s_2}\right)^n$ where $m, n \in N$
$e^{a_1t_1+a_2t_2}$	$\frac{s_1s_2}{(s_1-u_1a_1)(s_2-u_2a_2)}$ where $a, b \in R$





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$e^{-(a_1 t_1 + a_2 t_2)}$	$\frac{s_1 s_2}{(s_1 + u_1 a_1)(s_2 + u_2 a_2)}$
$\cos(a_1 t_1 + a_2 t_2)$	$\frac{s_1 s_2 (s_1 s_2 - a_1 a_2 u_1 u_2)}{(s_1^2 + u_1^2 a_1^2)(s_2^2 + a_2^2 u_2^2)}$
$\sin(a_1 t_1 + a_2 t_2)$	$\frac{s_2 s_2 (s_1 a_2 u_2 + s_2 a_1 u_1)}{(s_1^2 + u_1^2 a_1^2)(s_2^2 + a_2^2 u_2^2)}$
$\cosh(x)$	$\frac{1}{2} \left[\frac{s_1 s_2}{(s_1 - u_1 a_1)(s_2 - u_2 a_2)} + \frac{s_1 s_2}{(s_1 + u_1 a_1)(s_2 + u_2 a_2)} \right]$
$\sinh(x)$	$\frac{1}{2} \left[\frac{s_1 s_2}{(s_1 - u_1 a_1)(s_2 - u_2 a_2)} - \frac{s_1 s_2}{(s_1 + u_1 a_1)(s_2 + u_2 a_2)} \right]$
$\frac{\partial g(t_1, t_2)}{\partial t_1}$	$\frac{s_1}{u_1} R_{t_1} R_{t_2} [g(t_1, t_2)] - \frac{s_1}{u_1} R[g(0, t_2)]$
$\frac{\partial g(t_1, t_2)}{\partial t_2}$	$\frac{s_2}{u_2} R_{t_1} R_{t_2} [g(t_1, t_2)] - \frac{s_2}{u_2} R[g(t_1, 0)]$
$\frac{\partial^2 g(t_1, t_2)}{\partial t_1^2}$	$\frac{s_1^2}{u_1^2} R_{t_1} R_{t_2} [g(t_1, t_2)] - \frac{s_1^2}{u_1^2} R[g(0, t_2)] - \frac{s_1}{u_1} R[g_{t_1}(0, t_2)]$
$\frac{\partial^2 g(t_1, t_2)}{\partial t_2^2}$	$\frac{s_2^2}{u_2^2} R_{t_1} R_{t_2} [g(t_1, t_2)] - \frac{s_2^2}{u_2^2} R[g(t_1, 0)] - \frac{s_2}{u_2} R[g_{t_2}(t_1, 0)]$
$\frac{\partial^2 g(t_1, t_2)}{\partial t_1 \partial t_2}$	$\frac{s_1 s_2}{u_1 u_2} R_{t_1} R_{t_2} [g(t_1, t_2)] - \frac{s_1 s_2}{u_1 u_2} R[g(0, t_2)] - \frac{s_2}{u_2} R[g_{t_1}(t_1, 0)]$





Some Distance - based Topological Indices of Star Starbell Graph and Wheel Starbell Graph

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ABSTRACT

A topological index is an analytically derived numerical index for the graph structure. In this paper, we study some distance-based topological indices, such as, Wiener index (W), hyper-Wiener index (WW), Harary index (H), Reciprocal Complementary Wiener index (RCW), Wiener Polarity index (W_P), Terminal Wiener index (TW), Reverse Wiener index (Λ) and Reciprocal Reverse Wiener index ($R\Lambda$) of Star Starbell graph $SS_{m_1, m_2, \dots, m_{n-1}}$ and Wheel Starbell graph $WS_{m_1, m_2, \dots, m_{n-1}}$.

MSC:05C12, 05C76

Keywords: Wiener index, Hyper-Wiener index, Harary index, Reciprocal Complementary Wiener index, Wiener Polarity index, Terminal Wiener index, Reverse Wiener index Reciprocal Reverse Wiener index, Star Starbell graph and Wheel Starbell graph.

INTRODUCTION

In this paper, we consider only finite, undirected, connected and simple graphs. For a graph $G = (V, E)$, the number of vertices and edges will be denoted by $|V(G)|$ and $|E(G)|$ respectively. If $u, v \in V(G)$, length of the shortest distance between u and v in G is denoted by $d_G(u, v)$, we simply denote it by $d(u, v)$ if there is no ambiguity in the graph





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under consideration. The eccentricity of a vertex u in a graph G is $e(u) = \max\{d(u, v) : v \in V(G)\}$. The radius (resp. diameter) of G is $r = rad(G) = \min\{e(v) : v \in V(G)\}$ (resp. $d = diam(G) = \max\{e(v) : v \in V(G)\}$). In a graph, a vertex of degree 1 is known as a pendent vertex or terminal node or leaf node or leaf. Definitions which are not seen here can be referred in [1,2]. A topological index is an analytically derived numerical index for the graph structure. Indices are graph invariants used to study graph structure. Graph techniques have many applications in various fields such as Chemistry, Physics, Biology, Computer Science, etc. The Wiener index is the distance based topological index introduced by the chemist Harry Wiener in 1947 [3] and also known as the “Wiener number” [4,5]. Wiener index which is widely used based on the chemical applications of graph theory which counts the number of bonds between pairs of atoms and sum the distance between all pairs by generating a distance matrix [6]. The Wiener index is defined by the sum of distances between all unordered pairs of vertices of a graph G ,

$$W(G) = \sum_{u,v \in V(G)} d(u, v).$$

The hyper-Wiener index is the generalization of the Wiener index introduced by Milan Randić in 1993 [7] and is defined as follows:

$$WW(G) = \frac{1}{2} \sum_{u,v \in V(G)} [d(u, v) + d(u, v)^2].$$

In [8] Plavšić et. al., and In [9] Ivancine et. al., independently introduced the Harary index, in honor of Frank Harary.

For the graph G , the Harary index is defined as the reciprocal of the Wiener index, and denoted by

$$H(G) = \sum_{u,v \in V(G)} \frac{1}{d(u, v)}$$

In [10,11] Ivancine et. al., introduced the Reciprocal Complementary Wiener index, denoted by $RCW(G)$ and given

$$by RCW(G) = \sum_{u,v \in V(G)} \frac{1}{d+1-d(u,v)}$$

where d is the diameter of a graph G .

The Wiener Polarity index W_p of a graph G , is introduced by Wiener in 1947 [12], is the number of unordered pairs of vertices of G such that the distance between u and v is 3,

$$W_p(G) = |\{(u, v) | d(u, v) = 3, u, v \in V(G)\}|.$$

The Terminal Wiener index of a graph G is defined by Gutman et. al., in [13], as the sum of distance between all pairs of pendent vertices of G ,

$$TW(G) = \sum_{\substack{u,v \in V(G) \\ \deg(u)=\deg(v)=1}} d(u, v).$$

The Reverse Wiener index was proposed by Balaban et. al. in 2000 [14], is defined as follows

$$\wedge(G) = \frac{n(n-1)d}{2} - W(G),$$

where $n = |V(G)|$ and d is the diameter of G .

In [15], the Reciprocal Reverse Wiener (RRW) index $R \wedge(G)$ of a connected graph G is defined as

$$R \wedge(G) = \begin{cases} \sum_{u,v \in V(G)} \frac{1}{d-d(u,v)}, & \text{for } 0 < d(u, v) < d, \\ 0, & \text{for otherwise.} \end{cases}$$

where d is the diameter of a graph G .

In this paper we calculate $W(G)$, $WW(G)$, $H(G)$, $RCW(G)$, $W_p(G)$, $TW(G)$, $\wedge(G)$ and $R \wedge(G)$ of a Star Starbell and a Wheel Starbell graphs. Here we use some of the results and remarks, which will be used for proving the results. For $n \geq 2$, S_n denotes the star on n vertices in which one vertex is adjacent to all the other vertices, see Figure 1 for S_5 . Also $S_n \cong K_{1,n-1}$.

A W_n , $n \geq 4$ denotes the wheel on n vertices, in which a single vertex is connected to all the vertices of a cycle with $n - 1$ vertices, see Figure 2 for W_8 .

Lemma 1.1.[16] Let S_n and W_n be the star and wheel graphs of the order n , respectively. Then

- i. for $n \geq 1$, $W(S_n) = (n - 1)^2$
- ii. for $n \geq 4$, $W(W_n) = (n - 1)(n - 2)$.





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Lemma 1.2.^[16] Let S_n and W_n be the star and wheel graphs of the order n , respectively. Then

- i. for $n \geq 1$, $WW(S_n) = \frac{1}{2}(n - 1)(3n - 4)$
- ii. for $n \geq 4$, $WW(W_n) = \frac{1}{2}(n - 1)(3n - 8)$.

Lemma 1.3.^[17] Let S_n and W_n be the star and wheel graphs of the order n , respectively. Then

- i. for $n \geq 1$, $H(S_n) = \frac{1}{4}(n - 1)(n + 2)$
- ii. for $n \geq 4$, $H(W_n) = \frac{1}{4}(n - 1)(n + 4)$.

Lemma 1.4.^[18] Let S_n and W_n be the star and wheel graphs of the order n , respectively. Then

- i. for $n \geq 1$, $RCW(S_n) = \frac{1}{2}(n - 1)^2$
- ii. $RCW(W_n) = \begin{cases} 6, & \text{for } n = 4, \\ \frac{1}{2}(n - 1)(n - 2), & \text{for } n \geq 5. \end{cases}$

Lemma 1.5.^[12] Let S_n and W_n be the star and wheel graphs of the order n , respectively. Then $W_p(S_n) = W_p(W_n) = 0$.

Lemma 1.6.^[13,19] Let S_n and W_n be the star and wheel graphs of the order n , respectively. Then $TW(S_n) = (n - 1)(n - 2)$ and $TWW_n = 0$.

Lemma 1.7.^[20] Let S_n and W_n be the star and wheel graphs of the order n , respectively. Then

- i. for $n \geq 1$, $\Lambda(S_n) = (n - 1)$
- ii. $\Lambda(W_n) = \begin{cases} \frac{1}{2}(n - 1)(4 - n), & \text{for } n = 4, \\ 2(n - 1), & \text{for } n \geq 5. \end{cases}$

Lemma 1.8.^[21] Let S_n and W_n be the star and wheel graphs of the order n , respectively. Then

- i. for $n \geq 1$, $R \Lambda(S_n) = (n - 1)$
- ii. $R \Lambda(W_n) = \begin{cases} 0, & \text{for } n = 4, \\ 2(n - 1), & \text{for } n \geq 5. \end{cases}$

INDICES OF STAR STARBELL GRAPH.

In this section, we introduce star starbell graph $SS_{m_1, m_2, \dots, m_{n-1}}$ which is similar to starbarbell graph^[22] and also derive some results for distance-based topological indices $W(G)$, $WW(G)$, $H(G)$, $RCW(G)$, $W_p(G)$, $TW(G)$, $\Lambda(G)$ and $R \Lambda(G)$, where G is a star starbell graph.

Definition 2.1. The star starbell graph $SS_{m_1, m_2, \dots, m_{n-1}}$ is a graph obtained from a star S_n by augmenting root of a star S_{m_i} to i^{th} leaf of S_n , where each $m_i \geq 2$, $1 \leq i \leq n - 1$ and $n \geq 3$, see Figure 3, $SS_{m_1, m_2, \dots, m_{n-1}}$, when each $m_i = 4$ and $n = 5$. (The star S_{m_i} , $1 \leq i \leq n - 1$ is treated as bell)

Theorem 2.2. For $m \geq 2$ and $n \geq 3$ the star starbell graph $G = SS_{m_1, m_2, \dots, m_{n-1}}$, in which all the star S_{m_i} (bell) are of the same order. Then

- i. $W(G) = m(n - 1)[m + (n - 2)(2m - 1)]$.
- ii. $WW(G) = \frac{1}{2}(n - 1)[m(3m - 1) + (n - 2)(10m^2 - 8m + 1)]$.
- iii. $H(G) = \frac{(n-1)}{24}[6m(m + 3) + (n - 2)(3m^2 + 2m + 1)]$.
- iv. $RCW(G) = \frac{(n-1)}{12}[m(2m + 1) + 2(n - 2)(3m^2 - 3m + 1)]$.

Proof. Let $G = SS_{m_1, m_2, \dots, m_{n-1}}$ be the star starbell graph where each star graph S_{m_i} is of the





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same order with $m_i \geq 2, 1 \leq i \leq n - 1$ and $n \geq 3$. Let $m_i = m, i = 1, 2, \dots, n - 1$. Let $V(G) = \{v_0\} \cup V_1 \cup V_2 \cup \dots \cup V_{n-1}$, where $V_i = \{v_{i,1}, v_{i,2}, \dots, v_{i,m}\}, i = 1, 2, \dots, n - 1$. The distance between any two vertices in G are enumerated as, for $i, j = 1, 2, \dots, n - 1$ and $k, l = 2, 3, \dots, m$.

$$\begin{aligned} d(v_0, v_{i,1}) &= d(v_{i,1}, v_{i,k}) = 1, \\ d(v_0, v_{i,k}) &= d(v_{i,k}, v_{i,l}) = 2, \text{ for } k \neq l, \\ d(v_{i,1}, v_{j,1}) &= 2, \text{ for } i \neq j, \\ d(v_{i,1}, v_{j,k}) &= 3, \text{ for } i \neq j, \\ d(v_{i,k}, v_{j,l}) &= 4, \text{ for } i \neq j. \end{aligned}$$

Here $diam(G) = 4$. The distance between any pair of vertices varies from $1, 2, \dots, diam(G)$.

The number of 1 distance, pair of vertices is $(n - 1) + (n - 1)(m - 1)$.

The number of 2 distance, pair of vertices is $\binom{n-1}{2} + (n - 1)\binom{m-1}{2} + (n - 1)(m - 1)$.

The number of 3 distance, pair of vertices if $(n - 1)(n - 2)(m - 1)$.

The number of 4 distance, pair of vertices is $(m - 1)^2 \binom{n-1}{2}$.

By using these we derive the following

$$(i) W(G) = [(n - 1) + (n - 1)(m - 1)]1 + [\binom{n-1}{2} + (n - 1)\binom{m-1}{2} + (n - 1)(m - 1)]2 + [(n - 1)(n - 2)(m - 1)]3 + [(m - 1)^2 \binom{n-1}{2}]4 = m(n - 1)[m + (n - 2)(2m - 1)].$$

$$\begin{aligned} (ii) WW(G) &= \frac{1}{2} [(n - 1) + (n - 1)(m - 1)](1 + 1^2) + [\binom{n-1}{2} + (n - 1)\binom{m-1}{2} + (n - 1)(m - 1)](2 + 2^2) \\ &\quad + [(n - 1)(n - 2)(m - 1)](3 + 3^2) + [(m - 1)^2 \binom{n-1}{2}](4 + 4^2) \\ &= \frac{1}{2} (n - 1)[m(3m - 1) + (n - 2)(10m^2 - 8m + 1)]. \end{aligned}$$

$$(iii) H(G) = [(n - 1) + (n - 1)(m - 1)]\frac{1}{1} + [\binom{n-1}{2} + (n - 1)\binom{m-1}{2} + (n - 1)(m - 1)]\frac{1}{2} + [(n - 1)(n - 2)(m - 1)]\frac{1}{3} + [(m - 1)^2 \binom{n-1}{2}]\frac{1}{4} = \frac{(n-1)}{24} [6m(m + 3) + (n - 2)(3m^2 + 2m + 1)].$$

$$(iv) RCW(G) = [(n - 1) + (n - 1)(m - 1)]\frac{1}{4} + [\binom{n-1}{2} + (n - 1)\binom{m-1}{2} + (n - 1)(m - 1)]\frac{1}{3} + [(n - 1)(n - 2)(m - 1)]\frac{1}{2} + [(m - 1)^2 \binom{n-1}{2}]\frac{1}{1} = \frac{(n-1)}{12} [m(2m + 1) + 2(n - 2)(3m^2 - 3m + 1)].$$

Remark 2.1. In Theorem 2.2, when $n = 2$, the diameter of graph G is 2, hence $RCW(G)$ is invalid but $W(G), WW(G)$ and $H(G)$ are valid.

Corollary 2.3. For the star starbell graph G with $m \geq 2$ and $n \geq 3$,

$$W_p(G) = (n - 1)(n - 2)(m - 1).$$

Proof. The number of 3 distance pair of vertices is $(n - 1)(n - 2)(m - 1)$ by Theorem 2.2. So, $W_p(G) = (n - 1)(n - 2)(m - 1)$.

Corollary 2.4. For $m \geq 2$ and $n \geq 3$, the star starbell graph has the terminal Wiener index as

$$TW(G) = (n - 1)(m - 1)[(m - 2) + 2(m - 1)(n - 2)].$$

Proof. For $m \geq 2$, by Theorem 2.2 we have

$$\begin{aligned} TW(G) &= [(n - 1) \binom{m-1}{2}]2 + [(m - 1)^2 \binom{n-1}{2}]4 \\ &= (n - 1)(m - 1)[(m - 2) + 2(m - 1)(n - 2)]. \end{aligned}$$

Lemma 2.5. For the star starbell graph G with $m \geq 2$ and $n \geq 3$,

$$\Lambda(G) = 2[m(n - 1) + 1][m(n - 1)] - [m(n - 1)[m + (n - 2)(2m - 1)]].$$

Proof. For $m \geq 2$ and $n \geq 3$ the star starbell graph $G, |V(G)| = m(n - 1) + 1$, the diameter of G is 4 (i.e., $d = 4$) by Theorem 2.2 and $W(G) = m(n - 1)[m + (n - 2)(2m - 1)]$, hence

$$\Lambda(G) = 2[m(n - 1) + 1][m(n - 1)] - [m(n - 1)[m + (n - 2)(2m - 1)]].$$





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Lemma 2.6. For the star starbell graph G with $m \geq 2$ and $n \geq 3$,

$$R \wedge (G) = \frac{1}{12} (n - 1) [m(3m + 1) + 3(n - 2)(4m - 3)].$$

Proof. For $m \geq 2$ and $n \geq 3$, the star starbell graph G has the diameter $d = 4$, hence the distance between any pair of vertices varies from $0 < d(u, v) < d$.

The number of 1 distance, pair of vertices is $(n - 1) + (n - 1)(m - 1)$.

The number of 2 distance, pair of vertices is $\binom{n-1}{2} + (n - 1)\binom{m-1}{2} + (n - 1)(m - 1)$.

The number of 3 distance, pair of vertices is $(n - 1)(n - 2)(m - 1)$.

Then we have

$$\begin{aligned} R \wedge (G) &= [(n - 1) + (n - 1)(m - 1)] \frac{1}{3} + \left[\binom{n-1}{2} + (n - 1) \binom{m-1}{2} \right. \\ &\quad \left. + (n - 1)(m - 1) \right] \frac{1}{2} + [(n - 1)(n - 2)(m - 1)] \frac{1}{1} \\ &= \frac{1}{12} (n - 1) [m(3m + 1) + 3(n - 2)(4m - 3)]. \quad \square \end{aligned}$$

INDICES OF A WHEEL STARBELL GRAPH.

In this section, we introduce wheel starbell graph $WS_{m_1, m_2, \dots, m_{n-1}}$ which is similar to star starbell graph and also derive some results for distance-based topological indices $W(G)$, $WW(G)$, $H(G)$, $RCW(G)$, $W_p(G)$, $TW(G)$, $\wedge(G)$ and $R \wedge(G)$, where G is a wheel starbell graph.

Definition 3.1. The wheel starbell graph $WS_{m_1, m_2, \dots, m_{n-1}}$ is a graph obtained from wheel graph $W_n, n \geq 4$, by joining root vertex of a star graph $S_{m_i}, m_i \geq 2$, to all vertices in the cycle C_{n-1} of W_n , see Figure 3.1 for $WS_{m_1, m_2, \dots, m_5}$.

Theorem 3.2. For $m \geq 2$ and $n \geq 5$ the wheel starbell graph G , in which each star graph is of the uniform order. Then

(i) $W(G) = (n - 1) [(m + n - 3) + (m - 1)(m + 3n - 8) + (m - 1)^2(2n - 5)].$

(ii) $WW(G) = \frac{1}{2} (n - 1) [(20m + 3n - 28) + 3(m - 1)(m + 4n - 18) + 2(m - 1)^2(5n - 14)].$

(iii) $H(G) = \frac{1}{24} (n - 1) [6(4m + n) + 2(m - 1)(3m + 4n - 4) + (m - 1)^2(3n - 4)].$

(iv) $RCW(G) = \frac{1}{12} (n - 1) [(3m + 2n - 5) + 2(m - 1) [(m + 3n - 8) + 3(m - 1)(n - 3)]].$

Proof. Let $G = WS_{m_1, m_2, \dots, m_{n-1}}$ be the wheel starbell graph, where each star graph is of the uniform order with $m_i \geq 2, 1 \leq i \leq n - 1$ and $n \geq 5$. Let $m_i = m, i = 1, 2, \dots, n - 1$. Let $V(G) = \{v_0\} \cup V_1 \cup V_2 \cup \dots \cup V_{n-1}$, where $V_i = \{v_{i,1}, v_{i,2}, \dots, v_{i,m}\}, i = 1, 2, \dots, n - 1$. The distance between any two vertices in G are enumerated as, for $i, j = 1, 2, \dots, n - 1$ and $k, l = 2, 3, \dots, m$.

$d(v_0, v_{i,1}) = d(v_{i,1}, v_{i,k}) = 1,$

$d(v_{i,1}, v_{i+1,1}) = 1,$ where $i + 1$ can taken addition modulo $n - 1,$

$d(v_0, v_{i,k}) = d(v_{i,k}, v_{i,l}) = 2,$ for $k \neq l,$

$d(v_{i,1}, v_{i+1,k}) = d(v_{i,1}, v_{i-1,k}) = 2,$ where $i \pm 1$ can can taken addition modulo $n - 1,$

$d(v_{i,1}, v_{j,1}) = 2,$ for $j \neq i, i \pm 1,$ where j can can taken addition modulo $n - 1,$

$d(v_{i,1}, v_{j,k}) = 3,$ for $j \neq i, i \pm 1,$ where j can can taken addition modulo $n - 1,$

$d(v_{i,k}, v_{i+1,l}) = d(v_{i,k}, v_{i-1,l}) = 3,$ where $i \pm 1$ can can taken addition modulo $n - 1,$

$d(v_{i,k}, v_{j,l}) = 4,$ for $j \neq i, i \pm 1,$ where j can can taken addition modulo $n - 1,$

Here $diam(G) = 4$. The distance between any pair of vertices varies from $1, 2, \dots, diam(G)$.

The number of 1 distance, pair of vertices is $2(n - 1) + (n - 1)(m - 1)$.

The number of 2 distance, pair of vertices is $(n - 4) + \binom{n-3}{2} + 3(n - 1)(m - 1) + (n - 1)\binom{m-1}{2}$.

The number of 3 distance, pair of vertices is $(n - 1)(m - 1)(n - 4) + (m - 1)^2(n - 4) + 3(m - 1)^2$.

The number of 4 distance, pair of vertices is $(m - 1)^2(n - 4) + (m - 1)^2\binom{n-3}{2}$.

By using these we derive the following





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(i) $W(G) = [2(n - 1) + (n - 1)(m - 1)]1 + [(n - 4) + \binom{n-3}{2} + 3(n - 1)(m - 1) + (n - 1)\binom{m-1}{2}]2 + [(n - 1)(m - 1)(n - 4) + (m - 1)^2(n - 4) + 3(m - 1)^2]3 + [(m - 1)^2(n - 4) + (m - 1)^2\binom{n-3}{2}]4 = (n - 1)[(m + n - 3) + (m - 1)(m + 3n - 8) + (m - 1)^2(2n - 5)].$

(ii) $WW(G) = \frac{1}{2} [[2(n - 1) + (n - 1)(m - 1)](1 + 1^2) + [(n - 4) + \binom{n-3}{2} + 3(n - 1)(m - 1) + (n - 1)\binom{m-1}{2}](2 + 2^2) + [(n - 1)(m - 1)(n - 4) + (m - 1)^2(n - 4) + 3(m - 1)^2](3 + 3^2) + [(m - 1)^2(n - 4) + (m - 1)^2\binom{n-3}{2}](4 + 4^2)] = \frac{1}{2}(n - 1)[(20m + 3n - 28) + 3(m - 1)(m + 4n - 18) + 2(m - 1)^2(5n - 14)].$

(iii) $H(G) = [2(n - 1) + (n - 1)(m - 1)]\frac{1}{1} + [(n - 4) + \binom{n-3}{2} + 3(n - 1)(m - 1) + (n - 1)\binom{m-1}{2}]\frac{1}{2} + [(n - 1)(m - 1)(n - 4) + (m - 1)^2(n - 4) + 3(m - 1)^2]13 + [(m - 1)^2(n - 4) + (m - 1)^2\binom{n-3}{2}]14 = 124n - 1[64m + n + 2m - 13m + 4n - 4 + m - 123n - 4].$

(iv) $RCW(G) = [2(n - 1) + (n - 1)(m - 1)]\frac{1}{4} + [(n - 4) + \binom{n-3}{2} + 3(n - 1)(m - 1) + (n - 1)\binom{m-1}{2}]\frac{1}{3} + [(n - 1)(m - 1)(n - 4) + (m - 1)^2(n - 4) + 3(m - 1)^2]\frac{1}{2} + [(m - 1)^2(n - 4) + (m - 1)^2\binom{n-3}{2}]\frac{1}{1} = \frac{1}{12}(n - 1)[(3m + 2n - 5) + 2(m - 1)[3(m - 1)(n - 3) + (m + 3n - 8)]]$.

Remark 3.1. In Theorem 3.2, when $n = 4$, the diameter of graph G is 3, hence $RCW(G)$ is invalid but $W(G), WW(G)$ and $H(G)$ are valid.

Corollary 3.3. For the wheel starbell graph G with $m \geq 2$ and $n \geq 4$,

$W_p(G) = (n - 1)(m - 1)(m + n - 5).$

Proof. The number of 3 distance pair of vertices are $(n - 1)(m - 1)(n - 4) + (m - 1)^2(n - 4) + 3(m - 1)^2$ by Theorem 3.2. So, $W_p(G) = (n - 1)(m - 1)(m + n - 5).$

Corollary 3.4. For $m \geq 2$ and $n \geq 4$ the wheel starbell graph G has the terminal Wiener index as $TW(G) = (n - 1)(m - 14m - 5 + 2m - 1n - 4).$

Proof. For $m \geq 2$ and $n \geq 4$, by Theorem 3.2 we have

$TW(G) = (n - 1)\binom{m-1}{2}2 + (m - 1)^2(n - 1)3 + [(m - 1)^2(n - 4) + (m - 1)^2\binom{n-3}{2}]4 = (n - 1)(m - 1)[(4m - 5) + 2(m - 1)(n - 4)].$

Lemma 3.5. For the wheel starbell graph G with $m \geq 2$ and $n \geq 5$, $\Lambda(G) = 2[m(n - 1) + 1][m(n - 1)] - (n - 1m + n - 3 + m - 1m + 3n - 8 + m - 122n - 5).$

Proof. For $m \geq 2$ and $n \geq 5$, the wheel starbell graph $G, |V(G)| = m(n - 1) + 1$, the diameter of the graph G is 4 (i.e., $d = 4$) and $W(G) = (n - 1)[(m + n - 3) + (m - 1)(m + 3n - 8) + (m - 1)^2(2n - 5)].$ Then $\Lambda(G) = 2[m(n - 1) + 1][m(n - 1)] - (n - 1)[(m + n - 3) + (m - 1)(m + 3n - 8) + (m - 1)^2(2n - 5)].$

Lemma 3.6. For the wheel starbell graph G with $m \geq 2$ and $n \geq 5$, $RA(G) = \frac{1}{12}(n - 1)[4m(3m - 5) + (3n + 4) + 3m - 1m + 4n - 12].$

Proof. For $m \geq 2$ and $n \geq 5$, the wheel starbell graph G has the diameter $d = 4$ and the distance between any pair of vertices from $0 \leq d(u, v) \leq d$.

The number of 1 distance, pair of vertices is $2(n - 1) + (n - 1)(m - 1).$

The number of 2 distance, pair of vertices is $(n - 4) + \binom{n-3}{2} + 3(n - 1)(m - 1) + (n - 1)\binom{m-1}{2}.$

The number of 3 distance, pair of vertices is $(n - 1)(m - 1)(n - 4) + (m - 1)^2(n - 4) + 3(m - 1)^2.$

Then we have





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$$RA(G) = [2(n-1) + (n-1)(m-1)]\frac{1}{3} + [(n-4) + \binom{n-3}{2} + 3(n-1)(m-1) + (n-1)\binom{m-1}{2}] \frac{1}{2} + [(n-1)(m-1)(n-4) + (m-1)^2(n-4) + 3(m-1)^2] \frac{1}{1} = \frac{1}{12}(n-1)[4m(3m-5) + (3n+4) + 3(m-1)(m+4n-12)].$$

REFERENCES

1. R. Balakrishnan, K. Ranganathan, *A Textbook of Graph Theory*, Springer Science, New York, (2012).
2. J.A. Bondy, U.S.R. Murty, *Graph Theory with Applications*, Macmillan, New York, (1976).
3. H. Wiener, Structural determination of paraffin boiling points, *J. Am. Chem. Soc.* 69 (1947) 17-20.
4. K.C. Das, I. Gutman, Estimating the Wiener index by means of number of vertices, number of edges, and diameter, *MATCH Commun. Math. Comput. Chem.* 64 (2010) 647-660.
5. A.A. Dobrynin, R. Entringer, I. Gutman, Wiener index of trees: theory of applications, *Acta. Appl. Math.* 66 (2001) 211-249.
6. B. Mohar and T. Pisanski, How to compute the Wiener index of a graph, *J. Math. Chem.* 2 (1988) 267-277.
7. M. Randić, Novel molecular descriptor for structure-property studies, *Chem. Phys. Lett.* 211 (1993) 478-483.
8. D. Plavšić, S. Nikolić, N. Trinajstić, Z. Mihalić, On the Harary index for the characterization of chemical graphs, *J. math. Chem.* 12 (1993) 235-250.
9. O. Ivanciuc, T.S. Balaban, A.T. Balaban, Reciprocal distance matrix, related local vertex invariants and topological indices, *J. Math. Chem.* 12 (1993) 309-318.
10. O. Ivanciuc, QSAR comparative study of Wiener descriptors for weighted molecular graphs, *J. Chem. Inf. Comput. Sci.* 40 (2000) 1412-1422.
11. O. Ivanciuc, T. Ivanciuc, A.T. Balaban, The complementary distance matrix, a new molecular graph metric, *ACH Models Chem.* 137 (2000) 57-82.
12. H. Deng, H. Xiao, F. Tang, On the extremal Wiener polarity index of trees with a given diameter, *MATCH Commun. Math. Comput. Chem.* 63 (2010) 257-264.
13. I. Gutman, B. Furtula, M. Petrović, Terminal Wiener index, *J. Math. Chem.* 46 (2009) 522-531.
14. A.T. Balaban, D. Mills, O. Ivanciuc, S.C. Basak, Reverse Wiener indices, *Croat. Chem. Acta.* 73 (2000) 923-941.
15. O. Ivanciuc, T. Ivanciuc, A.T. Balaban, Quantitative structure property relationship valuation of structural descriptors derived from the distance and reverse Wiener matrices, *Internet Electron. J. Mol. Des.* 1 (2002) 467-487.
16. Ahmed Mohammed Ali, Some results on Wiener indices for a connected graph G , *Italian Journal of pure and Applied Mathematics*, 46 (2021) 391-399.
17. E.W. Weisstein, *Harary index – from wolfram mathworld*, <http://mathworld.wolfram.com/HararyIndex.html>, (2009).
18. R. Nasiri, A. Nakhaei, A.R. Shojaeifard, The Reciprocal Complementary Wiener number of graph operations, *Kragujevac Journal of Mathematics*, 45 (1) (2021) 139-154.
19. I. Gutman, B. Furtula, A survey on terminal Wiener index, in: I. Gutman, B. Furtula (Eds), *Novel Molecular Structure Descriptors – Theory and Applications I*, Univ. Kragujevac, Kragujevac, (2010) 173-190.
20. X. Cai, B. Zhou, Reverse Wiener indices of connected graphs, *MATCH Commun. Math. Comput. Chem.* 60 (2008) 95-105.
21. B. Zhou, Y. Yang, N. Trinajstić, On reciprocal reverse Wiener index, *J. Math. Chem.* 47 (2010) 201-209.
22. Babysuganya K, Sivasankar S, Some Distance-based Topological Indices of Starbarbell Graph and Wheelbarbell Graph. (Communicated)





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<p>Figure 1: Star Graph S_5</p>	<p>Figure 2: Wheel Graph W_8</p>
<p>Figure 3: Star Starbell Graph $SS_{4,4,4,4}$ where $m_i = 4, i = 1, 2, 3, 4$</p>	<p>Figure 4: Wheel Starbell Graph $WS_{4,4,4,4,4}$ where $m_i = 4, i = 1, 2, 3, 4, 5$</p>





Structure of a Graph Associated with Annihilator Ideals of \mathbb{Z}_n

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ABSTRACT

We define a graph associated with annihilator ideals of a ring R , termed as zero annihilating graph of R , which is an intersection graph whose vertex set is the set of all non-trivial ideals and any two vertices x and y of the graph are adjacent if and only if $ann(x) \cap ann(y) = 0$. We derive several characteristics of the zero annihilating graph, including its degree, girth, connectedness, and completeness. We also investigate the zero annihilating graph's domination and independence numbers.

Keywords: annihilator, intersection graph, girth, domination number independence number.

2020 Mathematics Subject Classification: 05C25, 05C40.

INTRODUCTION

There are numerous graph theoretical techniques available in algebraic graph theory to address algebraic problems. In 1964, J. Bosak defined a new type of graph on semi group structures termed as intersection graph [3]. The concept was further studied by B. Cs'ak'any and G. Poll'ak[5] in 1969. We have derived a new type of intersection graph on annihilators of ideals of a ring in this paper. First, we discuss the basic properties of a graph K . We denote the vertex set of K as $V(K)$ and edge set as $E(K)$. $deg(v_i)$ denotes the number of vertices adjacent to a vertex v_i . K is complete if all the vertices of K are adjacent. We use \bar{K} to denote the complement graph of K . A clique is a complete subgraph of K . Girth of K is the smallest cycle length exists in K , denoted by $girth(K)$. If there exists no cycle in K , then the girth of K is ∞ . We denote the magnitude of $E(K)$ by q . The largest distance between any two vertices of K is known as its diameter. It is denoted by $Diam(K)$. Lower domination number is the cardinality of the smallest set of vertices, known as dominating set, which are adjacent to all other vertex of K . Similarly, the connected domination number is the number of vertices in the smallest connected dominating set and the total dominating set is the cardinality of the dominating set, in which every vertex of the set has a neighborhood vertex in the set itself. The independence number is the cardinality of the largest set of non-adjacent vertices of K . Annihilator of an ideal I of a ring R , denoted





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by $ann(I)$ is defined as $ann(I) = \{r \in R: rx = 0, \forall x \in I\}$. A specific graph defined on annihilator ideal was studied by S. Salehifar, K. Khashyarmansh, and M. Afkhani in 2017[9]. M. J. Nikmehr, and S. M. Hosseini [8] in 2019 and J. Amjadi, R. Khoeilar, and A. Alilou[1] in 2021 also did some interesting works on some graphs associated with annihilator ideals. We use MATLAB to draw some zero annihilating graphs. One can locate any ambiguous phrase in [6, 7].

PRELIMINARIES

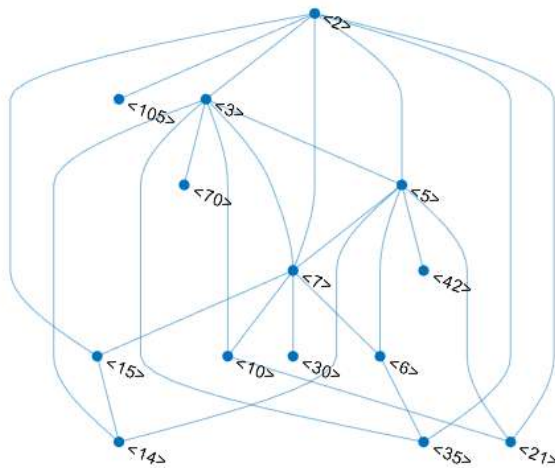
Definition 2.1: Zero annihilating graph of a ring R is a graph with vertices as its non-trivial ideals and two distinct vertices $\langle x \rangle$ and $\langle y \rangle$ are adjacent if and only if $ann(\langle x \rangle) \cap ann(\langle y \rangle) = 0$. It is denoted by $A(R)$.

Theorem 2.2: If $G \cong H$, then $A(G) \cong A(H)$.

Proof: Let us consider an isomorphism φ from G to H . Now we define a map ζ from $V(A(G))$ to $V(A(H))$ as $\zeta(x) = \varphi(x)$. Then we can easily conclude that $A(G) \cong A(H)$.

Remark 2.3: The converse of Theorem 2.2 is not true as $A(\mathbb{Z}_6) \cong A(\mathbb{Z}_{10})$, but $\mathbb{Z}_6 \not\cong \mathbb{Z}_{10}$.

Example 2.4: We have drawn the zero annihilating graph of \mathbb{Z}_{210} in Figure 1. It can be seen that the degrees of the vertices generated by the product of same number of prime numbers are equal. Also, $A(\mathbb{Z}_{210})$ contains cycles of length 3 and the minimal ideals of \mathbb{Z}_{210} in $A(\mathbb{Z}_{210})$ are pendant vertices.



Connectedness

Theorem 3.1: $A(\overline{\mathbb{Z}_{p^n}})$ is a complete graph.

Proof: For any two vertices x and y of $A(\overline{\mathbb{Z}_{p^n}})$, $\langle p^{n-1} \rangle \subseteq ann(\langle x \rangle) \cap ann(\langle y \rangle)$. Therefore, x and y are not adjacent. Hence, $A(\overline{\mathbb{Z}_{p^n}})$ is a complete graph.

Theorem 3.2: In $A(\mathbb{Z}_n)$, where $n = \prod_{i=1}^k p_i$, p_i 's are distinct primes, $\langle x \rangle$ and $\langle y \rangle$ are adjacent if and only if x and y are coprime.

Proof: Let $\langle x \rangle$ and $\langle y \rangle$ be two adjacent vertices. Then $ann(\langle x \rangle) \cap ann(\langle y \rangle) = 0$. If possible, assume that $gcd(x, y) = d \neq 1$. Then d does not divide both the generators of $ann(\langle x \rangle)$ and $ann(\langle y \rangle)$. This implies that $ann(\langle x \rangle) \cap ann(\langle y \rangle) \neq 0$, a contradiction. Therefore, x and y are coprime. On the other hand, consider that x and y are coprime. Then it is obvious that $ann(\langle x \rangle) \cap ann(\langle y \rangle) = 0$.

Corollary 3.3: The minimal ideals in $A(\mathbb{Z}_n)$, where $n = \prod_{i=1}^k p_i$, p_i 's are distinct primes, are pendant vertices.





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Theorem 3.4: In $\mathbb{A}(\mathbb{Z}_n)$, where $n = \prod_{i=1}^k p_i$, p_i 's are distinct primes, the prime ideals form a clique.

Proof: Since, the generators x and y of two distinct prime ideals are coprime, therefore they are adjacent by Theorem 3.2. Hence, the prime ideals form a complete subgraph.

Theorem 3.5: $\mathbb{A}(\mathbb{Z}_{\prod_{i=1}^k p_i})$ is complete if and only if $k = 2$.

Proof: For $k > 2$, there exists a vertex $\langle p_i \rangle$ which is not adjacent to $\langle p_i p_{i+1} \rangle$ or $\langle p_{i-1} p_i \rangle$. Hence the theorem.

Theorem 3.6: $\mathbb{A}(\mathbb{Z}_{\prod_{i=1}^k p_i})$, is connected, where p_i 's are distinct primes.

Proof: We have by Theorem 3.4 that the ideals generated by primes are mutually adjacent. Now, greatest common divisor of generator of any other vertex of $\mathbb{A}(\mathbb{Z}_{\prod_{i=1}^k p_i})$, is 1 with at least one of the prime ideals. Therefore, by Theorem 2.2, $\mathbb{A}(\mathbb{Z}_{\prod_{i=1}^k p_i})$, is connected.

Theorem 3.7: $\text{girth}(\mathbb{A}(\mathbb{Z}_{\prod_{i=1}^k p_i})) = 3$ or ∞ .

Proof: For $k \geq 3$, the result holds from Theorem 3.4. For $k = 2$ and 1, the result is obvious.

Theorem 3.8: In $\mathbb{A}(\mathbb{Z}_{\prod_{i=1}^k p_i})$, $\text{deg}(\langle \prod_{i=1}^l p_i \rangle) = \sum_{i=1}^{k-l} \binom{k-l}{i}$.

Proof: From Theorem 3.2, we get $\langle \prod_{i=1}^l p_i \rangle$ is adjacent to all the vertices generated by the divisors of $\frac{\prod_{i=1}^k p_i}{\prod_{i=1}^l p_i}$. On counting, we have $\sum_{i=1}^{k-l} \binom{k-l}{i}$ such vertices. Hence the theorem.

Theorem 3.9: $q = \frac{1}{2} \sum_{j=1}^{k-1} \left\{ \binom{k}{j} \sum_{i=1}^{k-j} \binom{k-j}{i} \right\}$.

Proof: There are $\binom{k}{j}$ vertices of degree $\sum_{i=1}^{k-j} \binom{k-j}{i}$. Proceeding this way from $j = 1$ to k , we get the required size of the graph.

Theorem 3.10: $\text{Diam}(\mathbb{A}(\mathbb{Z}_{\prod_{i=1}^k p_i}))$ is not more than 4.

Proof: Let $\langle x \rangle$ and $\langle y \rangle$ be two non-adjacent vertices of $\mathbb{A}(\mathbb{Z}_{\prod_{i=1}^k p_i})$. Then x and y cannot be coprime. We have two cases:

Case 1: Assume that $\langle x \rangle$ and $\langle y \rangle$ are not minimal ideals of $\mathbb{Z}_{\prod_{i=1}^k p_i}$ and $\text{gcd}(x,y) = d \neq 1$. Then we have the following subcases:

Subcase 1.1: Let $\text{lcm}(x,y) = s \neq \prod_{i=1}^k p_i$. Then $\langle x \rangle - \langle \frac{\prod_{i=1}^k p_i}{s} \rangle - \langle y \rangle$ is a path having 3 vertices. In this case distance is 3.

Subcase 1.2: If $\text{lcm}(x,y) = s = \prod_{i=1}^k p_i$, then $\langle x \rangle - \langle \frac{s}{d} \rangle - \langle \frac{s}{d} \rangle - \langle y \rangle$ is a path having 4 vertices.

Case 2: Consider that one of $\langle x \rangle$ and $\langle y \rangle$, say $\langle x \rangle$ be minimal and the other is not and $\text{gcd}(x,y) = d \neq 1$. Proceeding in the way as Case 1, we get the same results.

Case 3: Consider that both of $\langle x \rangle$ and $\langle y \rangle$ are minimal ideals of $\mathbb{Z}_{\prod_{i=1}^k p_i}$. Then there exists two prime ideals $\langle p_i \rangle$ and $\langle p_j \rangle$ such that $\langle x \rangle - \langle p_i \rangle - \langle p_j \rangle - \langle y \rangle$ is a path and the pairs $(\langle p_j \rangle, \langle x \rangle)$ and $(\langle p_i \rangle, \langle y \rangle)$ are not mutually adjacent. In this case diameter is 4.

Domination number and independence number

Theorem 4.1:

- (i) Lower domination number of $\mathbb{A}(\mathbb{Z}_{\prod_{i=1}^k p_i})$ is k .
- (ii) Connected domination number of $\mathbb{A}(\mathbb{Z}_{\prod_{i=1}^k p_i})$ is k .
- (iii) Total domination number of $\mathbb{A}(\mathbb{Z}_{\prod_{i=1}^k p_i})$ is k .





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Proof:

(i) It can be observed that any two minimal ideals of $\mathbb{Z}_{\prod_{i=1}^k p_i}$ are not adjacent to the same vertex. Therefore, we need as many as number of minimal ideals of $\mathbb{Z}_{\prod_{i=1}^k p_i}$. Now the set of all prime ideals are adjacent to all other vertex and it is the smallest to satisfy this property. Hence, lower domination number of $\mathbb{A}(\mathbb{Z}_{\prod_{i=1}^k p_i})$ is k .

(ii) Since, the prime ideals are mutually adjacent, therefore the dominating set made above is connected. Hence, connected domination number of $\mathbb{A}(\mathbb{Z}_{\prod_{i=1}^k p_i})$ is k .

(iii) Since, the dominating set made above is connected, therefore, every vertex of the set has a neighborhood in the set itself. Hence, total domination number of $\mathbb{A}(\mathbb{Z}_{\prod_{i=1}^k p_i})$ is k .

Theorem 4.2: $\alpha(\mathbb{A}(\mathbb{Z}_{\prod_{i=1}^k p_i}))$ is $\binom{k}{k-1} + \binom{k}{k-2} + \dots + \binom{k}{k - \frac{k-1}{2}}$, if k is odd and $\binom{k}{k-1} + \binom{k}{k-2} + \dots + \binom{k}{k - (\frac{k}{2} - 1)} + \frac{1}{2} \binom{k}{k - \frac{k}{2}}$, if k is even.

Proof: We have the following cases:

(i) Let k be odd. Then by Theorem 3.2, all the vertices of the type $\langle p_{i_1} p_{i_2} \dots p_{i_m} \rangle, i_l \in \{1, 2, \dots, k\}, i_l \neq i_j$ if $l \neq j, m \geq \frac{k+1}{2}$ are mutually non-adjacent. Therefore, they form an independent set. Any other vertex of $\mathbb{A}(\mathbb{Z}_{\prod_{i=1}^k p_i})$ is adjacent to at least one of the previous types of vertices by Theorem 2.2. Therefore, the set containing those types of vertices is the largest independent set. On counting, we have $\binom{k}{k-1} + \binom{k}{k-2} + \dots + \binom{k}{k - \frac{k-1}{2}}$ such vertices.

(ii) Let k be even. Then following the way as the first part, all the vertices of the type $\langle p_{i_1} p_{i_2} \dots p_{i_m} \rangle, i_l \in \{1, 2, \dots, k\}, i_l \neq i_j$ if $l \neq j, m \geq \frac{k}{2} + 1$ are mutually non-adjacent. Also, half of the type $\langle p_{i_1} p_{i_2} \dots p_{i_{\frac{k}{2}}} \rangle, i_l \in \{1, 2, \dots, k\}, i_l \neq i_j$ are mutually non-adjacent, which are also non-adjacent to the previous vertices. On counting, we have $\binom{k}{k-1} + \binom{k}{k-2} + \dots + \binom{k}{k - (\frac{k}{2} - 1)} + \frac{1}{2} \binom{k}{k - \frac{k}{2}}$ such vertices. Following the proof of the first part, we have the required result.

REFERENCES

1. J. Amjadi, R. Khoelilar, and A. Alilou, The annihilator-inclusion Ideal graph of a commutative ring, *Communications in Combinatorics and Optimization*, (2021) Vol. 6, 231-248, DOI: 10.22049/cco.2020.26752.1139
2. D. F. Anderson, and A. Badawi, The total graph of a commutative ring, *J. Algebra*, 320(2008), no. 7, pp. 2706-2719.
3. J. Bosak, The graphs of semigroups in: *Theory of graphs and application*, Academic Press, New York, 1964, pp. 119-125.
4. I. Chakrabarty, S. Ghosh, T. K. Mukherjee, and M. K. Sen, Intersection graphs of ideals of rings, *Discrete Math.*, 309(2009), no. 17, pp. 5381-5392
5. B. Cs'ak'any, G. Poll'ak, The graph of subgroups of a finite group (Russian), *Czechoslovak Math. J.* 19 (1969) 241 – 247. DOI: <https://doi.org/10.21136/CMJ.1969.100891>
6. D. S. Dummitt, and R. M. Foote, (2004) *Abstract Algebra*. 3rd Edition, John Wiley & Sons, Inc
7. F. Harary, *Graph theory*, Addison-Wesley Publishing Company, Inc., Reading, Mass., 1969.
8. M. J. Nikmehr, and S. M. Hosseini, More on the annihilator-ideal graph of a commutative ring, *Journal of Algebra and Its Applications*, (2019), DOI: 10.1142/S0219498819501603
9. S. Salehifar, K. Khashyarmanesh, and M. Afkhami. On the annihilator-ideal graph of commutative rings., *Ricerche mat*, 66, 431–447 (2017). <https://doi.org/10.1007/s11587-016-0311-y>





A Decision Making Problem based on Neutrosophic Soft Expert Set to Analyse the Components that Cause Cancer

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ABSTRACT

In this paper, we apply the entropy method to calculate the weights of each alternative. These weights are then used to frame the three most common algorithms-TOPSIS, WSM and WPM to solve the Neutrosophic Soft Expert Set based decision making problems. In addition, python coding is employed to calculate the performance score of each alternative. Further, the efficiency and accuracy of the suggested methods are discussed. Finally, the alternatives are ranked according to their performance score.

Keywords: Soft set, Neutrosophic set, Neutrosophic soft set, Neutrosophic soft expert set(NSES), TOPSIS, WSM, WPM.

2020 Subject Classification: Primary 54-08; Secondary 65G20.

INTRODUCTION

“Yoon and Hwang [1] first introduced the TOPSIS method. Tien-chin Wang, et.al., [2] in 2009, proposed fuzzy TOPSIS method to evaluate alternatives w.r.to multiple criteria in MCDM problems. In 2013, Wenyan Song, et.al., [3] used rough group TOPSIS method to evaluate the risk of failure mode, which integrates the strength of rough set theory in handling vagueness and adds the merit of TOPSIS in modeling multi-criteria decision making. Hu-chen Liu, et.al., [4] in 2014 introduced intuitionistic fuzzy hybrid TOPSIS approach, to determine the risk priorities of failure modes. Xiaolu Zhang, et.al., [5] developed a soft computing technique in 2015 based on maximizing consensus and fuzzy TOPSIS in order to solve interval-valued intuitionistic fuzzy MAGDM problems. In 2018 [6] proposed





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intuitionistic fuzzy hybrid TOPSIS approach to deal with limitations of a crisp risk matrix and uncertainties of group decision makers using experts' opinion in linguistic terms. In 2019, Yasir Ahmed Solangi, et.al., [7] applied Fuzzy-TOPSIS method in ranking of 13 energy strategies. Xianfeng Liu, et.al., [8] in 2019 proposed an entropy-based TOPSIS model to measure the maturity of seven pilot carbon markets in China from 2013-2017. Similarly, Ayse METIN KARAKAS, et.al., [9] used entropy method to obtain the volatility of 1. and 2. degree earthquake zones on the same fault line. In 2020, Aytac YILDIZ, et.al., [10] applied TOPSIS, GRA and ANP methods to evaluate the alternative socks export markets. Vajrala Venkata REDDY [11] elaborated the process involved in optimization studies in turning process with multi-response features on the basis of MCDM methodologies by utilizing the CRITIC and TOPSIS approaches. Arshia Kaul, et.al., [12] utilized TOPSIS to evaluate which of the plants in the firm has been able to implement the lean-green strategy in manufacturing of medical equipment.

Shivam Prajapati, et.al., [13] presented a novel hybrid fuzzy AHP-TOPSIS approach. Similarly, in 2021 Ajit Kumar Singh, et.al., [14] proposed an industry-oriented quality management method with the help of integrated QFD-TOPSIS. Later on in 2021 Karter Singh, et.al., [15] used ANOVA and TOPSIS method to optimize the tribological performance of polymer composites. Mehdi Jahangiri, et.al., [16] applied TOPSIS approach to evaluate the potential of all capital cities of Iran in terms of solar-based hydrogen production and also to prioritize the nominated alternatives. Melda KOKOC, et.al., [17] compared the performance of different entropy measures developed for Interval-valued intuitionistic fuzzy sets. In 2022 Kilic, et.al., [18] applied IVIF-DEMATEL method for the criteria evaluation and the weight determination phase and further applied IVIF-TOPSIS to evaluate hotel information system alternatives. Liu, et.al., [19] developed TOPSIS approach by integrating both fuzzy criteria and stochastic criteria, for the selection of service suppliers. Lakshmana kumar, et.al., [20] incorporated TOPSIS method to solve multi-objective optimization in dry turning of super alloy nimonic c263. Jing Ye, et.al., [21] used TOPSIS approach to choose the best cotton fabric." "The main aim of this paper is to present an application of Neutrosophic soft expert set in decision making problem using TOPSIS, WSM and WPM. Surapati pramanik, et.al., [22] used TOPSIS method in Single valued neutrosophic soft expert set based multi-attribute decision making problems. Similarly, Xindong peng et.al., [23] solved Single-valued neutrosophic MADM based on MABAC, TOPSIS and new similarity measures with score function algorithm. In 2018, Harish garg et.al., [24] applied TOPSIS method for interval-valued intuitionistic fuzzy sets using connection number SPA theory. In 2019, Muhammad Saqlain, et.al., [25] applied TOPSIS method for Neutrosophic hypersoft sets using accuracy function. Later on Muhammad saqlain, et.al., [26] constructed NHSSS-TOPSIS for Distance and similarity measures of Neutrosophic hypersoft sets. In this paper we use TOPSIS, WSM and WPM methods along with entropy method that aids in calculation of weights of the corresponding attributes. Finally, the comparison between 3 methodologies are discussed and the alternatives are ranked based on their performance score."

PRELIMINARIES

In this section some basic notions are given which would be helpful to read this paper. Throughout this paper Neutrosophic soft expert sets are denoted by NSES.

Definition 2.1. [27]

"Let U be an initial universe set and E be a set of parameters. Let $P(U)$ denote the power set of U . Consider a nonempty set $B \subset E$. A pair (G, B) is called a Soft set over U , where G is a mapping given by $G : B \rightarrow P(U)$. A soft set over U is a parameterized family of subsets of the universe U . For $\varepsilon \in B$, $G(\varepsilon)$ may be considered as the set of ε -approximate elements of the soft set (G, B) ."

Definition 2.2. [28]

"A neutrosophic set C on the universal set Z is attributed by three individualistic degrees namely, truth-membership degree T , indeterminacy-membership degree I and falsity-membership degree F , which is defined as; $C = \{ \langle z, T_C(z), I_C(z), F_C(z) \rangle : z \in Z \}$





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where $T_C, I_C, F_C : Z \rightarrow]-0, 1^+$ and $0 \leq T_C(z) + I_C(z) + F_C(z) \leq 3^+.$

Definition 2.3. [29]

“A neutrosophic soft set h over Z is a neutrosophic set valued function from E to $N(Z)$. It can be written as $h = \{(e, \{< z, T_{h(e)}(z), I_{h(e)}(z), F_{h(e)}(z) > : z \in Z\}) : e \in E\}$ where, $N(Z)$ denotes all neutrosophic sets over $Z.$ ”

Definition 2.4. [30]

“The process/mathematical form of conversion of neutrosophic numbers N into crisp numbers is said to be accuracy function.”

$$A(N) = \frac{[T(x) + I(x) + F(x)]}{3} : x \in N.$$

Definition 2.5. [31]

“A pair (F, A) is called a neutrosophic soft expert set over U , where F is a mapping given by $F : A \rightarrow P(U)$, where $P(U)$ denotes the power neutrosophic set of $U.$ ”

ALGORITHM FOR TOPSIS, WSM AND WPM METHODS

Analysis

In this section, we present an application of MADM problem for NSES through 3 methodologies TOPSIS, WSM and WPM. “Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), Weighted Sum Model (WSM) and Weighted Product Model (WPM)” are most popular methods in solving MADM and MCDM problems.

TOPSIS Algorithm

TOPSIS is a multi-criteria decision analysis method that stands for “Technique for Order of Preference by Similarity to Ideal Solution”. Weights and distances are the two components of TOPSIS. It is based on ideal optimal and ideal suboptimal values. The ideal optimal is one that maximizes the beneficial criteria and minimizes the cost criteria. The ideal suboptimal is one that maximizes the cost criteria and minimizes the beneficial criteria. Alternatives are rated using an overall index based on the distances from the ideal solutions.

1. Construct a NSES based on the alternatives, attributes and experts chosen in the problem.
2. Transfer Neutrosophic numbers into Crisp numbers using Accuracy function.
3. Construct a Normalized decision matrix using;

$$n_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^m x_{ij}^2}}, \quad j = 1, 2, \dots, n, \quad i = 1, 2, \dots, m$$

4. Calculate weighted normalized decision matrix, $w_{ij} = w_j * n_{ij}$, for which $\sum_{j=1}^n w_j = 1$, where

$$w_j = \frac{1 - e_j}{\sum_{j=1}^n 1 - e_j}, \quad j = 1, 2, \dots, n,$$

$$e_j = -h \sum_{i=1}^m n_{ij} \ln(n_{ij}), \quad j = 1, 2, \dots, n,$$

$$h = \frac{1}{\ln^h(u)}$$

here u is the number of alternatives.

5. Determine Ideal best and Ideal worst value.

For $E^+ = \{e_1, e_2\}$, where $w_j^+ = \{\max(w_{ij}) \text{ if } j \in J; \min(w_{ij}) \text{ if } j \in J^+\}$,

For $E^- = \{e_1, e_2\}$, where $w_j^- = \{\min(w_{ij}) \text{ if } j \in J; \max(w_{ij}) \text{ if } j \in J^-\}$.

6. Determine the Euclidean Distance from the Ideal best and Ideal worst value using;





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For positive ideal: $D_i^+ = \sqrt{\sum_{j=1}^n (w_{ij} - w_j^+)^2}$, $i = 1, 2, \dots, m$

For negative ideal: $D_i^- = \sqrt{\sum_{j=1}^n (w_{ij} - w_j^-)^2}$, $i = 1, 2, \dots, m$

7. Evaluate the Performance Score of each alternative by;

$$P_i = \frac{D_i^-}{D_i^+ + D_i^-}, 0 < P_i < 1, \quad i = 1, 2, \dots, m,$$

$$P_i = 1, \text{ if } e_i = E^+, P_i = 0, \text{ if } e_i = E^-$$

8. Rank the alternatives based on the Performance Score.

WSM Algorithm

WSM is a multi-criteria decision-making approach where we must select the best alternative among several alternatives based on the parameters chosen. The “Weighted Sum Method” is often referred to as the “Simple Additive Method (or) Weighted Linear Combination” in decision making.

1. Step 1-4 follows as of TOPSIS Algorithm.
2. Evaluate $S_i^{WSM} = \sum_{j=1}^n w_{ij}$, $i = 1, 2, \dots, m$.
3. $\max(\sum_{j=1}^n w_{ij}, i = 1, 2, \dots, m)$ will be the best alternative.

WPM Algorithm

The “Weighted Product Method” is a multi-criteria decision-making method in which numerous alternatives are present and the best alternative is determined based on multiple criteria. It uses multiplication to calculate attribute rating.

1. Step 1-3 follows as of TOPSIS Algorithm.
2. Calculate weighted normalized decision matrix, $w_{ij} = n_{ij}^{w_j}$, for which $\sum_{j=1}^n w_j = 1$, where

$$w_j = \frac{1 - e_j}{\sum_{j=1}^n 1 - e_j}, \quad j = 1, 2, \dots, n,$$

$$e_j = -h \sum_{i=1}^m n_{ij} \ln(n_{ij}), \quad j = 1, 2, \dots, n,$$

$$h = \frac{1}{\ln(u)}$$

here u is the number of alternatives.

3. Evaluate $S_i^{WPM} = \prod_{j=1}^n w_{ij}$, $i = 1, 2, \dots, m$.
4. $\max(\prod_{j=1}^n w_{ij}, i = 1, 2, \dots, m)$ will be the best alternative.

APPLICATION OF NSES

Example

In recent years, many people are being affected by cancer. The substances that cause cancer is known as carcinogens. Let U be an universal set which consist of some reasons that cause cancer, where $U = \{u_1 = \text{alcohol consumption}, u_2 = \text{smoking}, u_3 = \text{hazardous chemicals}\}$. Let the attribute set E consist of two types of cancers that are mainly caused by the alternatives chosen. Here, $E = \{e_1 = \text{lung cancer}, e_2 = \text{throat cancer}\}$. Main aim is to identify which of the alternative u_i is the major cause of lung and throat cancer. Let $G = \{a, b\}$ be the set of expert and $C = \{0, 1\}$ be the opinion set.

Construction of NSES

- $(e_1, a, 1) = \{(u_1, 0.6, 0.2, 0.2), (u_2, 0.8, 0.1, 0.2), (u_3, 0.4, 0.4, 0.6)\}$,
- $(e_2, a, 1) = \{(u_1, 0.7, 0.2, 0.1), (u_2, 0.6, 0.2, 0.3), (u_3, 0.5, 0.3, 0.4)\}$,
- $(e_1, b, 1) = \{(u_1, 0.8, 0.1, 0.1), (u_2, 0.5, 0.2, 0.6), (u_3, 0.6, 0.4, 0.1)\}$,
- $(e_2, b, 1) = \{(u_1, 0.4, 0.5, 0.2), (u_2, 0.8, 0.2, 0.3), (u_3, 0.5, 0.4, 0.3)\}$,
- $(e_1, a, 0) = \{(u_1, 0.5, 0.3, 0.4), (u_2, 0.2, 0.6, 0.6), (u_3, 0.5, 0.3, 0.4)\}$,





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$(e_2, a, 0) = \{(u_1, 0.4, 0.8, 0.6), (u_2, 0.5, 0.4, 0.6), (u_3, 0.6, 0.2, 0.5)\}$,
 $(e_1, b, 0) = \{(u_1, 0.6, 0.3, 0.4), (u_2, 0.2, 0.8, 0.1), (u_3, 0.3, 0.7, 0.2)\}$,
 $(e_2, b, 0) = \{(u_1, 0.3, 0.7, 0.6), (u_2, 0.6, 0.4, 0.4), (u_3, 0.7, 0.1, 0.1)\}$.

To solve the above example we apply the TOPSIS, WSM and WPM algorithms programmed using python. The python programming results are obtained as under,

```
>>> print(TOPSIS)
alcohol consumption  0.573299
smoking              0.581920
hazardous chemicals  0.363227
dtype: float64
>>> print(WSM)
alcohol consumption  0.575044
smoking              0.590828
hazardous chemicals  0.552539
dtype: float64
>>> print(WPM)
alcohol consumption  0.570319
smoking              0.589169
hazardous chemicals  0.545364
dtype: float64
```

Graphical and Tabular comparison of alternatives using TOPSIS, WSM and WPM:

The TOPSIS, WSM and WPM techniques are used to compare the performance scores of each alternative. Out of three-alternatives smoking comes in first, alcohol consumption comes in second and hazardous chemicals come in third, which leads us to the conclusion that smoking is the primary cause in lung and throat cancer.

	TOPSIS	WSM	WPM	Rank
u_1	0.573299	0.575044	0.570319	2
u_2	0.581920	0.590828	0.589169	1
u_3	0.363227	0.552539	0.545364	3

In this section, we have proposed three approaches to solve the NSES based MADM problem. The first method TOPSIS is based on weights, ideal solution and distance. The second method WSM relies upon weight and summation. The third method WPM is determined by weight and product. Three different methods are compared. The values obtained are nearly identical in all three methods and the ranking of alternatives is the same in all three methods. Subsequently, we infer that the proposed methodologies are more accurate to solve NSES based MADM problems. The graphical Comparison of alternatives using TOPSIS, WSM and WPM algorithms is shown in Figure 1.

CONCLUSION

In this paper we have developed python coding for TOPSIS, WSM and WPM to solve MADM problems on NSES. Here entropy method is used to determine the weight of each attribute. Further the comparison between the alternatives based on performance score obtained in each method is presented graphically. Finally, we have shown that the proposed methodologies gives more accurate value and are more stable and practical to solve expert set based decision making problems.





REFERENCES

1. K. Yoon, C. L. Hwang, "Multiple Attribute Decision Making: Methods and Applications," New York: Springer-Verlag, 1981.
2. Tien-Chin Wang, Hsien-Da Lee, "Developing a fuzzy TOPSIS approach based on subjective weights and objective weights," *Expert Systems with Applications*, <https://doi.org/10.1016/j.eswa.2008.11.035>, Volume 36, Issue 5: pp. 8980-8985, July 2009.
3. Wenyan Song, Xinguo Ming, Zhenyong Wu, Baoting Zhu, "A rough TOPSIS Approach for Failure Mode and Effects Analysis in Uncertain Environments," *Quality and Reliability Engineering International*, <https://doi.org/10.1002/qre.1500>, 07 February 2013.
4. Hu-Chen Liu, Jian-Xin You, Meng-Meng Shan, Lu-Ning Shao, "Failure mode and effects analysis using intuitionistic fuzzy hybrid TOPSIS approach," *Soft Computing Article Methodologies and Application*, 04 June 2014.
5. Xiaolu Zhang, Zeshui Xu, "Soft computing based on maximizing consensus and fuzzy TOPSIS approach to interval-valued intuitionistic fuzzy group decision making," *Applied Soft Computing*, <https://doi.org/10.1016/j.asoc.2014.08.073>, Volume 26, pp. 42-56, January 2015.
6. "Risk assessment based on novel intuitionistic fuzzy-hybrid-modified TOPSIS approach," *Safety Science*, Volume 110 Part A: pp. 438-448, December 2018.
7. Yasir Ahmed Solangi, Qingmei Tan, Nayyar Hussain Mirjat, Sharafat Ali, "Evaluating the strategies for sustainable energy planning in Pakistan: An integrated SWOT-AHP and Fuzzy-TOPSIS approach," *Journal of Cleaner Production*, Volume 236: 117655, 1 November 2019.
8. Xianfeng Liu, Xinxing Zhou, Bangzhu Zhu, Kaijian He, Ping Wang, "Measuring the maturity of carbon market in China: An entropy-based TOPSIS approach," *Journal of Cleaner Production*, <https://doi.org/10.1016/j.jclepro.2019.04.380>, Volume 229, pp. 94-103, 20 August 2019;
9. Ayse METIN KARAKAS, Sinan CALIK, "Entropy method for earthquake volatility," *Sigma journal of engineering and natural sciences*, 38(1): pp. 329-348, 2020.
10. Aytac YILDIZ, Ahmet OZBEK, "Selection of socks export markets for turkey using multi-criteria decision making methods," *Sigma journal of engineering and natural sciences*, 38(2): pp. 795-815, 2020.
11. Vajrala Venkata REDDY, "Turning process parameters optimization of AL7075 hybrid MMC'S composite using TOPSIS method," *Sigma journal of engineering and natural sciences*, 38(4): pp. 2043-2055, 2020.
12. Arshia Kaul, Anindo Bhattacharjee, "Performance Evaluation of Lean-Green Healthcare Manufacturing Plants: A Fuzzy TOPSIS Approach," *Lean and Green Manufacturing*, pp 45-61, 17 October 2021.
13. Shivam Prajapati, Yogesh Upadhyay, Aviral Chharia, Bikramjit Sharma, "A novel hybrid Fuzzy AHP-TOPSIS Approach towards Enhanced multi-criteria Feature-based EV Recommender System," *2nd Global Conference for Advancement in Technology (GCAT)*, 2021.
14. Ajit Kumar Singh, A. M. Rawani, "Industry oriented quality management of engineering education: an integrated QFD-TOPSIS approach," *International Journal of System Assurance Engineering and Management Article*, volume 13, pp. 904-922, 18 September 2021.
15. Kartar Singh, Moti Lal Rinawa, Naseem Ahamad, Vijay Chaudhary, Partha Pratim Das, Sumit Gupta, Pallav Gupta, "Optimization of tribiological performance of natural fibers/epoxy composites using ANOVA and TOPSIS approach," *Materials Today: Proceedings*, <https://doi.org/10.1016/j.matpr.2021.09.112>, Volume 56, Part 5, pp. 2549-2555, 2022.
16. Mehdi Jahangiri, Mostafa Rezaei, Ali Mostafaeipour, Afsaneh Raiesi Goojani, Hamed Saghaei, Seyyed Jalaladdin Hosseini Dehshiri, Seyyed Shahabaddin Hosseini Dehshiri, "Prioritization of solar electricity and hydrogen co-production stations considering PV losses and different types of solar trackers: A TOPSIS approach. *Renewable Energy*," Volume 186: pp. 889-903, March 2022.
17. Melda KOKOC, Siileyman ERSOZ, "A comparison of the performance of entropy measures for interval-valued intuitionistic fuzzy sets," *Sigma journal of engineering and natural sciences*, Vol. 39, Issue 2, pp. 131-147, June 2021.





Jayasudha and Raghavi

18. Kilic Huseyin Selcuka, Kalender Zeynep Tugcea, Yalcin Ahmet Selcukb, Erkal Gizema, Tuzkaya Gulfema, "Information system selection for hospitality industry via integrated use of IVIF-DEMATEL and IVIF-TOPSIS," *Journal of Intelligent and Fuzzy Systems*, vol. 42: no. 1: pp. 317-335, 2022.
19. Liu Meng, Wang Xiaolin, Li Yupeng, "Service supplier selection under fuzzy and stochastic uncertain environments," *Journal of Intelligent and Fuzzy Systems*, vol. 42: no. 3: pp. 1301-1315, 2022.
20. S. Lakshmana Kumar, M. Subburaj, Arul Kulandaivel, P. Manoj Kumar, A. Thanikasalam, Raj Kumar, "Multiple response optimization of machining parameters in turning nimonic C263 using TOPSIS approach," *Materials Today*, Volume 59: Part 2: pp. 1414-1419, 2022.
21. Jing Ye, Ting-Yu Chen, "Selection of Cotton Fabrics Using Pythagorean Fuzzy TOPSIS Approach," *Journal of Natural Fibers*, <https://doi.org/10.1080/15440478.2021.1982439> Volume 19, Issue 14, pp. 9085-9100, 2022.
22. Surapati Pramanik, Partha Pratim Dey, Bibhas C. Giri, "TOPSIS for Single Valued Neutrosophic Soft Expert Set Based Multi-attribute Decision Making Problems," *Neutrosophic Sets and Systems*, 10: pp. 88-95, 2015.
23. Xindong Peng, Jingguo Dai, "Approaches to single-valued neutrosophic MADM based on MABAC, TOPSIS and new similarity measure with score function," *Neural Computing and Application*, 2016.
24. Harish Garg, Kamal Kumar, "A novel exponential distance and its based TOPSIS method for interval-valued intuitionistic fuzzy sets using connection number of SPA theory," 2018.
25. Muhammad Saqlain, Muhammad Saeed, Muhammad Rayees Ahmad, Florentin Smarandache, "Generalization of TOPSIS for Neutrosophic Hypersoft set using Accuracy Function and its Application," *Neutrosophic Sets and Systems*, 27: pp. 131-137, 2019.
26. Muhammad Saqlain, Muhammad Riaz, Muhammad Adeel Saleem, Miin-shen Yang, "Distance and Similarity Measures for Neutrosophic Hypersoft Set (NHSS) With Construction of NHSS-TOPSIS and Applications," *IEEE Access*, 9: 30803-30816, 2021.
27. D. Molodtsov, "Soft set theory-first results," *Computers and Mathematics with Applications*, 37 (4/5): pp. 19-31, 1999.
28. F. Smarandache, "Neutrosophic Soft Set, a generalisation of the intuitionistic fuzzy sets," *International Journal of Applied Mathematics*, 24: pp. 2466-2475, 2005.
29. Faruk Karaaslan, "Neutrosophic Soft sets with Applications in Decision Making," *International Journal of Information Science and Intelligent System*, 2015.
30. R. Sahin, "Multi-criteria neutrosophic decision making method based on score and accuracy functions under neutrosophic environment," arXiv:1412.5202, 2014.
31. Mehmet Sahin, Shawkat Alkhazaleh, Vakkas Ulucay, "Neutrosophic Soft Expert Sets," *Applied Mathematics*, 6: pp. 116-127, 2015.

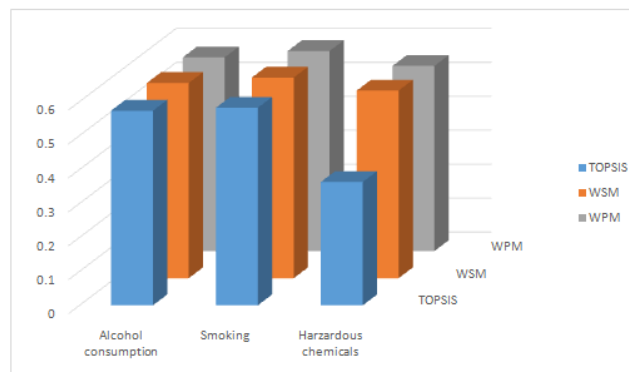


Figure 1: Ranking of Alternatives using TOPSIS, WSM and WPM Algorithms





A Mathematical Perspective behind Atmospheric Chemistry

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ABSTRACT

This paper describes the relationship between atmospheric chemistry and mathematical modeling methods. Atmospheric chemistry is the branch of chemistry that focuses on the chemical composition and reactions taking place in Earth's atmosphere. It involves the study of various atmospheric constituents, including gases (e.g., nitrogen, oxygen, carbon dioxide), aerosols, and pollutants (e.g., sulfur dioxide, ozone, volatile organic compounds). Researchers in this field aim to understand the sources, sinks, transformations, and transport of these constituents in the atmosphere. Mathematical models are essential tools for studying complex systems like the Earth's atmosphere. They help scientists simulate and predict atmospheric processes. Models in atmospheric chemistry often involve sets of differential equations that describe the rates of chemical reactions, transport of species, and physical processes like diffusion and convection. These models can be one-dimensional, two-dimensional, or three-dimensional depending on the complexity of the system being studied. Various mathematical techniques used in atmospheric modeling are numerical integration methods (e.g., finite difference, finite element, or finite volume methods), computational fluid dynamics (CFD) etc. Data assimilation techniques are crucial for incorporating observational data into models, improving their accuracy and reliability. Advanced modeling tools may involve solving partial differential equations (PDEs) for atmospheric dynamics and chemistry. A comprehensive overview of the role and significance of mathematical modeling in addressing economic issues, environmental issues and atmospheric chemistry is studied in this paper. Atmospheric chemistry models and mathematical methods contribute significantly to our understanding of the Earth's atmosphere, supporting various fields ranging from environmental science to public policy and climate research. These models help policymakers and scientists understand how pollutants



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disperse, how chemical reactions affect air quality, and how greenhouse gases contribute to climate change.

Keywords: Atmospheric Chemistry, Mathematical Modelling, Computation Fluid Dynamics, Finite Difference Methods, Partial Differential Equations

INTRODUCTION

The interdisciplinary nature of atmospheric chemistry models and mathematical methods allows researchers and decision-makers to approach complex environmental issues from a comprehensive standpoint. Advancements in computational capabilities and data assimilation techniques continue to improve the accuracy and reliability of these models, further enhancing their utility across various domains. Mathematical modeling plays a significant role in the study of atmospheric chemistry by providing a quantitative framework for understanding, predicting, and optimizing various chemical processes and their environmental impact. It serves as a powerful tool for understanding, analyzing, and solving complex problems that arise in the intersection of human society, economics, and the environment. Mathematical modeling involves multiple disciplines such as technology, science, economics, biology, demographics, social sciences, and politics. This interdisciplinary approach allows for a holistic understanding of real-world phenomena. Mathematical models also provide a quantitative description of real systems and their interactions with the external environment. The range of applications for mathematical modeling in economic-environmental research is vast. It spans topics like economic growth, technological development, population dynamics, resource extraction, environmental pollution, climate change, and global dynamics. Integrated mathematical models are constructed by studying simple components, allowing researchers to understand the connections among various economic, population, and environmental models.

Atmospheric chemistry is a young and rapidly growing science, motivated by the societal need to understand and predict human perturbation to atmospheric composition. This perturbation has increased greatly over the past century due to population growth, industrialization, and energy demand fueled by combustion. It is responsible for a range of environmental problems including degradation of air quality, deposition to ecosystems, depletion of stratospheric ozone, and climate change. Quantifying the link between human activities and their atmospheric effects is essential to the development of sound environmental policy. Atmospheric chemistry models and mathematical methods find applications in various areas, including air quality prediction, climate change studies, weather forecasting, and pollution control. These applications collectively contribute to addressing environmental challenges, protecting public health, and informing policy decisions.

Objectives of the study

Studying the mathematical perspective behind atmospheric chemistry involves applying mathematical models and techniques to understand the complex processes occurring in the Earth's atmosphere. The objectives of this study are

- To study different mathematical models to represent the physical and chemical processes that occurs in the atmosphere. This may include reactions between different chemical species, transport of pollutants, and the influence of meteorological factors.
- To gain a quantitative understanding of the concentrations and distributions of various atmospheric constituents and to study mathematical models to describe how different species interact and change over time and space.
- To provide a scientific basis for environmental policies and decision making. By understanding the mathematical relationships governing atmospheric chemistry, policymakers can make informed choices to mitigate pollution and address climate-related issues.
- To facilitate collaboration between mathematicians, chemists, physicists, and atmospheric scientists to develop comprehensive models that capture the interdisciplinary nature of atmospheric chemistry.



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This study emphasizes to enhance the education and training of scientists and engineers by integrating mathematical perspectives into atmospheric chemistry studies which will help to prepare researchers to tackle complex environmental challenges.

LITERATURE REVIEW

Knowledge of the relationship between emissions by a source and pollutant concentrations in the air at later times and other places (that is, the source/receptor relationship) is essential for calculating the exposure of humans to these pollutants and hence to predict the health impacts resulting from these source emissions. Mathematical models have evolved as the most practical means to relate source emissions to the subsequent air pollution concentrations and models used in air pollution analysis fall into two types: empirical/ statistical and analytical/deterministic. In the former, the model statistically relates observed air quality data to the accompanying emission patterns, whereas chemistry and meteorology are included only implicitly [32]. Mathematical models integrate our knowledge of the chemical and physical processes of pollutant dynamics into a structured framework that can be used to explain the relationship between sources such as motor vehicle exhaust and the resulting impact on human health [45]. Studies on the sources and chemical reactivity of Polynuclear Aromatic Hydrocarbons (PAH) in the atmosphere was reviewed [25]. The possibilities of modelling the photochemical mechanisms of the reactions of oxygen-, hydrogen-, nitrogen-, sulphur-, and carbon-containing compounds in the background atmosphere and in air in polluted regions and the selection of the parametrisation conditions in conformity with the aims of the given tasks and the hydrometeorological regime are analysed by Penenko and Skubnevskaya [27].

Mathematical models for estimating atmospheric chemical concentrations reviewed by Venkatram and Seigneur [44]. According to Brasseur and Jacob [4], the modeling of atmospheric chemistry is an intrinsically interdisciplinary endeavour, bringing together meteorology, radiative transfer, physical chemistry and biogeochemistry. An overview of atmospheric chemistry that is incorporated into air quality mechanisms is explained by Stockwell et. al. [35-36]. Mathematical models of gas leakage and its propagation in atmospheric air at an emergency gas well gushing is developed [48] and mathematical modeling of the thermochemical processes of nitrogen oxides sequestration during combustion of wood-coal mixture particles is studied [18]. The possibility of reducing the level of anthropogenic emissions of sulfur oxides, when burning coal fuel together with moisture-saturated woody biomass is explained with mathematical modeling [38]. Solution of the mathematical model of atmospheric internal waves phenomenon by Elzaki Adomian Decomposition Method was also studied [42]. Various mathematical models like Life Cycle Assessment, Molecular Dynamic, Bayesian, Chemical Thermodynamic, Computational Fluid Dynamics, Quantitative Structure Activity Relationship models etc. are studied by many researchers [7-12, 14-17, 19-20, 22, 26, 29-34, 39-40, 46]. The impact of oil and gas industry production on the environment, taking into account emergency situations using mathematical modeling of the impact of emergency situations on atmospheric air is studied [49]. Various mathematical methods used to study atmospheric chemistry are explained [13]. Theoretical framework for air pollution complex is explained [52]. Mathematical modeling of diesel and aromatic auto thermal reforming process is performed by Zazhigalov et.al.[50].

Mathematical Modeling

Mathematical models are tools that simulate the atmospheric processes governing the dispersion, transformation, and removal of pollutants over time and space. These integrate scientific knowledge of meteorology, atmospheric chemistry, and physics to represent the behavior of pollutants in the atmosphere. By inputting emission data and meteorological information, these models can predict the concentrations of pollutants at different locations and times. There are various types of models, range from simple box models for specific locations to complex three-dimensional models covering entire regions. The several ways in which mathematical modeling is used in the context of atmospheric chemistry are described in Table 1.



**Hema Sukhija and Aarti Trehan****Challenges**

- Models are based on simplifications and assumptions, and their accuracy depends on the quality of input data and the appropriateness of the model structure.
- Local variations, such as topography and specific emission patterns, can challenge the accuracy of predictions.

In the field of chemistry, various mathematical models are used for different purposes, ranging from describing molecular structures to predict reaction kinetics and assessing environmental impacts. These models serve different purposes and are applied in various sub-disciplines of chemistry to understand, predict, and optimize different aspects of chemical systems. These models cater to different aspects of green chemistry, from understanding chemical reactions and molecular properties to assessing the environmental impact of processes. Various mathematical models are employed to study different aspects of atmospheric chemistry. Some key mathematical models used in the field, ranging from understanding molecular interactions to predicting the environmental impact of chemical processes are discussed in Table 2. Now, these practical examples illustrate how each mathematical model type is applied in the study of atmospheric chemistry, contributing to the optimization and sustainability of chemical processes. The use of these models can lead to more informed decision-making and the development of environmentally friendly chemical practices. The integration of these models can provide a comprehensive understanding and optimization of environmentally sustainable chemical processes. Application and practical application of different mathematical models used for study of atmospheric chemistry are explained in Table 3. Studying the real-life applications of different mathematical models holds paramount importance in modern education and research. This endeavor serves as a bridge between abstract mathematical concepts and their practical implications in various domains. By delving into real-world scenarios, researchers gain a profound understanding of how mathematical principles can be harnessed to analyze, interpret, and solve complex problems encountered in fields such as engineering, economics, biology, and beyond.

Moreover, the study of real-life applications fosters critical thinking and problem-solving skills, empowering individuals to navigate and contribute meaningfully to a wide array of challenges spanning from optimizing industrial processes to managing environmental resources. Additionally, it cultivates interdisciplinary connections, highlighting the interconnectedness of different disciplines and encouraging collaboration across domains. Furthermore, as technology continues to advance and data becomes increasingly abundant, proficiency in mathematical modeling becomes indispensable for making informed decisions, driving innovation, and addressing pressing societal issues. In essence, the study of real-life applications of mathematical models not only enriches educational experiences but also equips individuals with the tools necessary to thrive in an ever-evolving world. Therefore, real life applications of different models are also explained in Table 4. These applications illustrate how mathematical models in atmospheric chemistry contribute to real-world applications by guiding decision-making, optimizing processes, and promoting sustainability in various chemical industries. There isn't a one-size-fits-all answer to which mathematical model is better for the study of atmospheric chemistry, as the choice often depends on the specific aspect of Green Chemistry being investigated and the nature of the system under consideration. Different mathematical models serve different purposes, and their effectiveness varies based on the context. The Table 2, provides a general overview, and the choice of a model depends on the specific objectives of the study, available data, and the complexity of the chemical system under investigation. Often, a combination of models is used to provide a more comprehensive understanding of atmospheric chemistry processes. The strengths and limitations mentioned in the table are generalizations, and the applicability of each model depends on the specific research questions and characteristics of the chemical systems being studied. Often, a combination of these models is used to address different aspects of Green Chemistry comprehensively. Here, a brief comparison of three commonly used mathematical models (Life Cycle Assessment (LCA), Reaction Kinetics Modeling and Process Systems Engineering (PSE)) in the field of atmospheric chemistry is explained in Table 5.



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DISCUSSION AND ANALYSIS

There isn't a particular model that can model all problems. The choice between kinetic models and LCA models depends on the specific goals of the study. In Table 6, Comparison between LCA and RKM on the basis of their scope, complexity and data requirements is shown

LCA is better when

- Evaluating the overall sustainability of a product or process.
- Considering a system with various interconnected stages.
- Making comparisons between different products or processes.

Reaction kinetics modeling is better when

- Focusing on optimizing chemical reactions and processes.
- Investigating the specific details of reaction mechanisms.
- Designing more efficient and environmentally friendly synthetic routes.

The choice between two mathematical models used for the study of atmospheric chemistry depends on the specific application, the nature of the chemical processes under consideration, and the data available. In many cases, a combination of both models may be the most effective approach, as it allows for a comprehensive understanding of the chemical processes at a detailed level (kinetic models) and their broader environmental implications (LCA models). Integrated approaches that combine different modeling techniques can provide a more holistic and informed perspective, contributing to the development of sustainable and environmentally friendly chemical processes. The choice of a mathematical model in the study of atmospheric chemistry depends on the specific application and the nature of the problem being addressed. Further, comparison between LCA and PSE modeling is explained in Table 7. PSE is more process-centric and is valuable for optimizing specific unit operations, improving reaction conditions, and minimizing waste generation. It is instrumental in the design of green and sustainable chemical processes.

From these comparisons, it is analyzed that mathematical model selection depends upon

1. **Goal:** The choice between different models depends on the specific goals of the study. For example if the primary concern is overall environmental impact assessment and comparison, LCA may be more suitable and if the focus is on optimizing a specific chemical process, PSE is the preferred choice.
2. **Complementary Use:** In many cases, We can use different models in integrated form like both LCA and PSE can be used in a complementary manner. Combining life cycle thinking with process optimization can lead to more sustainable and environmentally friendly solutions. Ultimately, the suitability of a mathematical model depends on the objectives of the study and the level of detail required for the analysis.

CONCLUSION

Mathematical models play a crucial role in understanding the complex relationship between emissions, pollutant concentrations, and human health. They are valuable tools for environmental scientists, policymakers, and public health officials working to mitigate the impacts of air pollution. By employing mathematical modeling, researchers in atmospheric chemistry can make informed decisions, optimize processes, and design eco-friendly products with reduced environmental impact. This interdisciplinary approach fosters the development of more sustainable and environmentally responsible chemical practices. Overall the choice of mathematical model depends on the research goals and the specific aspects of green chemistry being studied. Often, a combination of different models is used to provide a more complete and integrated understanding of the environmental impact of chemical processes. Both LCA and PSE are valuable tools in the toolkit of researchers working towards more sustainable practices in





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atmospheric chemistry. Researchers need to carefully choose and integrate models based on the specific characteristics of their study.

REFERENCES

1. Abbatt, J. P., & Ravishankara, A. R. (2023). Opinion: Atmospheric multiphase chemistry—past, present, and future. *Atmospheric Chemistry and Physics*, 23(17), 9765-9785.
2. Abdi, G., Patil, N., Jain, M., & Barwant, M. (2024). Integration of Metabolomics and Flux Balance Analysis: Applications and Challenges. *Advances in Bioinformatics*, 199-237.
3. Anderson, J. D., & Wendt, J. (1995). *Computational fluid dynamics* (Vol. 206, p. 332). New York: McGraw-hill.
4. Brasseur, G. P., & Jacob, D. J. (2017). *Modeling of atmospheric chemistry*. Cambridge University Press.
5. Chi, C., Han, W., & Thévenin, D. (2023). Effects of molecular diffusion modeling on turbulent premixed NH₃/H₂/air flames. *Proceedings of the Combustion Institute*, 39(2), 2259-2268.
6. Chopra, A., Subramanian, J., Krishnamurthy, B., & Raskar, R. (2023). AgentTorch: Agent-based Modeling with Automatic Differentiation. In *Second Agent Learning in Open-Endedness Workshop*.
7. Cramer, C. J. (2013). *Essentials of computational chemistry: theories and models*. John Wiley & Sons.
8. Cramer, C. J., & Truhlar, D. G. (2009). Density functional theory for transition metals and transition metal chemistry. *Physical Chemistry Chemical Physics*, 11(46), 10757-10816.
9. Curran, M. A. (2006). *Life-cycle assessment: principles and practice*. National Risk Management Research Laboratory, Office of Research and Development, US Environmental Protection Agency.
10. DeGroot, M. H., & Schervish, M. J. (2012). Probability and statistics.[SI]. *Pearson Education*, 19, 33.
11. Gelman, A., Carlin, J. B., Stern, H. S., & Rubin, D. B. (1995). *Bayesian data analysis*. Chapman and Hall/CRC.
12. Gelman, A., et al. (2014). *Bayesian Data Analysis*. CRC Press.
13. Gromotka, Z. (2023). *Hierarchical Mathematical Models of Chemical Processes* (Doctoral dissertation, Ghent University).
14. Guggenheim, E. A. (1950). Thermodynamics. An advanced treatment for chemists and physicists. *Zeitschrift für Naturforschung A*, 5(4), 236-236.
15. Heijungs, R., & Suh, S. (2002). *The computational structure of life cycle assessment* (Vol. 11). Springer Science & Business Media.
16. Jensen, F. (2017). *Introduction to computational chemistry*. John Wiley & Sons.
17. Juretic, D. (2021). *Bioenergetics: a bridge across life and universe*. CRC Press.
18. Kuznetsov, G. V., Syrodoy, S. V., Gutareva, N. Y., & Nigay, N. A. (2021). Mathematical modeling of the thermochemical processes of nitrogen oxides sequestration during combustion of wood-coal mixture particles. *Journal of the Energy Institute*, 96, 280-293.
19. Leach, A. R. (2001). *Molecular modelling: principles and applications*. Pearson education.
20. Liao, K., Wang, Q., Wang, S., & Yu, J. Z. (2023). Bayesian inference approach to quantify primary and secondary organic carbon in fine particulate matter using major species measurements. *Environmental Science & Technology*, 57(13), 5169-5179.
21. Martin, M., Gani, R., & Mujtaba, I. M. (2022). Sustainable process synthesis, design, and analysis: Challenges and opportunities. *Sustainable Production and Consumption*, 30, 686-705.
22. Maryasin, B., Marquetand, P., & Maulide, N. (2018). Machine learning for organic synthesis: are robots replacing chemists?. *Angewandte Chemie (International ed. in English)*, 57(24), 6978.
23. Milousis, A., Tsimpidi, A. P., Tost, H., Pandis, S. N., Nenes, A., Kiendler-Scharr, A., & Karydis, V. A. (2023). Implementation of the ISORROPIA-lite Aerosol Thermodynamics Model into the EMAC Chemistry Climate Model 2.56: Implications for Aerosol Composition and Acidity. *Geoscientific Model Development Discussions*, 2023, 1-33.
24. Nguyen, L. T., Hoang, G. H. L., Tran, U. N. P., Mai, T. V. T., Nguyen, H. D., & Huynh, L. K. (2023). Mechanistic and Kinetic Insights into OH-Initiated Atmospheric Oxidation of Hymexazol: A Computational Study. *Environmental Science & Technology*, 57(40), 15138-15152.



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25. Nikolaou, K., Masclet, P., & Mouvier, G. (1984). Sources and chemical reactivity of polynuclear aromatic hydrocarbons in the atmosphere—A critical review. *Science of the Total Environment*, 32(2), 103-132.
26. Orth, J. D., Thiele, I., & Palsson, B. Ø. (2010). What is flux balance analysis?. *Nature biotechnology*, 28(3), 245-248.
27. Penenko, V. V., & Skubnevskaya, G. I. E. (1990). Mathematical modelling in problems of the chemistry of the atmosphere. *Russian Chemical Reviews*, 59(11), 1024.
28. Place, B. K., Hutzell, W. T., Appel, K. W., Farrell, S., Valin, L., Murphy, B. N., ... & Pye, H. O. (2023). Sensitivity of Northeast US surface ozone predictions to the representation of atmospheric chemistry in CRACMMv1.0. *EGUsphere*, 2023, 1-30.
29. Rossi, F., Zuffi, C., Parisi, M. L., Fiaschi, D., & Manfrida, G. (2023). Comparative scenario-based LCA of renewable energy technologies focused on the end-of-life evaluation. *Journal of Cleaner Production*, 405, 136931.
30. Roy, K. (Ed.). (2020). *Ecotoxicological QSARs*. Humana Press.
31. Schuh, A. E., & Jacobson, A. R. (2023). Uncertainty in parameterized convection remains a key obstacle for estimating surface fluxes of carbon dioxide. *Atmospheric Chemistry and Physics*, 23(11), 6285-6297.
32. Seinfeld, J.H. 1975. *Air Pollution: Physical and Chemical Fundamentals*, McGraw-Hill, New York.
33. Seinfeld, J. H. (1986). ES&T books: atmospheric chemistry and physics of air pollution. *Environmental science & technology*, 20(9), 863-863.
34. Shoombuatong, W., Prathipati, P., Owasirikul, W., Worachartcheewan, A., Simeon, S., Anuwongcharoen, N., ... & Nantasenamat, C. (2017). Towards the revival of interpretable QSAR models. *Advances in QSAR modeling: applications in pharmaceutical, chemical, food, agricultural and environmental sciences*, 3-55.
35. Stockwell, W. R., Lawson, C. V., Saunders, E., & Goliff, W. S. (2011). A review of tropospheric atmospheric chemistry and gas-phase chemical mechanisms for air quality modeling. *Atmosphere*, 3(1), 1-32.
36. Stockwell, W. R., Saunders, E., Goliff, W. S., & Fitzgerald, R. M. (2020). A perspective on the development of gas-phase chemical mechanisms for Eulerian air quality models. *Journal of the Air & Waste Management Association*, 70(1), 44-70.
37. Sun, W. Y. (2023). Challenges and Progress in Computational Geophysical Fluid Dynamics in Recent Decades. *Atmosphere*, 14(9), 1324.
38. Syrodoy, S. V., Kuznetsov, G. V., Gutareva, N. Y., & Nigay, N. A. (2022). Mathematical modeling of the thermochemical processes of sequestration of SO_x when burning the particles of the coal and wood mixture. *Renewable Energy*, 185, 1392-1409.
39. Tkatchenko, A., & Scheffler, M. (2009). Accurate molecular van der Waals interactions from ground-state electron density and free-atom reference data. *Physical review letters*, 102(7), 073005.
40. Tropsha, A. (2010). Best practices for QSAR model development, validation, and exploitation. *Molecular informatics*, 29(6-7), 476-488.
41. Valentini, P., Grover, M. S., Verhoff, A. M., & Bisek, N. J. (2023). Near-continuum, hypersonic oxygen flow over a double cone simulated by direct simulation Monte Carlo informed from quantum chemistry. *Journal of Fluid Mechanics*, 966, A32.
42. Varsoliwala, A. C., & Singh, T. R. (2022). Mathematical modeling of atmospheric internal waves phenomenon and its solution by Elzaki Adomian decomposition method. *Journal of Ocean Engineering and Science*, 7(3), 203-212.
43. Velegar, M. (2023). *Reduced Order Model for Global Atmospheric Chemistry Data* (Doctoral dissertation, University of Washington).
44. Venkatram, A., & Seigneur, C. (1993). Review of mathematical models for health risk assessment: II. Atmospheric chemical concentrations. *Environmental Software*, 8(2), 75-90.
45. Watson, D. (1988). Intraindividual and interindividual Analyses of Positive and Negative Affect: Their Relation to Health Complaints, Perceived Stress, and Daily Activities. *Journal of Personality and Social Psychology*, 54, 1020-1030.
<http://dx.doi.org/10.1037/0022-3514.54.6.1020>
46. Watson, J. G., Henry, R. C., Cooper, J. A., & Macias, E. S. (1981). The state of the art of receptor models relating ambient suspended particulate matter to sources.





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47. Worden, J. R., Cusworth, D. H., Qu, Z., Yin, Y., Zhang, Y., Bloom, A. A., ... & Jacob, D. J. (2022). The 2019 methane budget and uncertainties at 1 resolution and each country through Bayesian integration Of GOSAT total column methane data and a priori inventory estimates. *Atmospheric Chemistry and Physics*, 22(10), 6811-6841.
48. Yatsyshyn, T., Shkitsa, L., Popov, O., & Liakh, M. (2019). Development of mathematical models of gas leakage and its propagation in atmospheric air at an emergency gas well gushing. *Восточно-Европейский журнал передовых технологий*, (5 (10)), 49-59.
49. Zaurbekova, N. D., Zaurbekov, N. S., Aidosov, A., Reginbayeva, N. A., Amanbayev, A. A., & Zaurbekova, G. N. (2023). Mathematical modeling of the impact of emergency situations on atmospheric air. In *E3S Web of Conferences* (Vol. 462, p. 03025). EDP Sciences.
50. Zazhigalov, S. V., Shilov, V. A., Kireenkov, V. V., Kulikov, A. V., Burmatova, M. A., Rogozhnikov, V. N., ... & Snytnikov, P. V. (2024). Stationary and dynamic mathematical modeling of autothermal reforming of diesel with aromatic compounds. *International Journal of Hydrogen Energy*, 61, 831-839.
51. Zhang, Y., Xie, L., Zhang, D., Xu, X., & Xu, L. (2023). Application of Machine Learning Methods to Predict the Air Half-Lives of Persistent Organic Pollutants. *Molecules*, 28(22), 7457.
52. Zhu, T., Tang, M., Gao, M., Bi, X., Cao, J., Che, H...& Zhu, J. (2023). Recent progress in atmospheric chemistry research in China: establishing a theoretical framework for the "air pollution complex". *Advances in Atmospheric Sciences*, 40(8), 1339-1361.

Table 1: Applications of mathematical modeling in study of atmospheric chemistry

Application	Purpose/Scope
Chemical Processes Optimization	Modeling reactions to reduce waste, energy consumption, and environmental impact.
Solvent Selection	Optimizing solvent usage by modeling their environmental and economic impact.
Catalyst Design	Developing efficient catalysts through mathematical models for green and sustainable reactions.
Life Cycle Assessment	Modeling the environmental impact of chemical processes from raw materials to disposal.
Waste Reduction	Designing processes to minimize by-products and enhance resource efficiency.
Renewable Resources Integration	Modeling the incorporation of renewable feedstocks in chemical production.
Eco-Friendly Product Design	Using mathematical models to design products with minimal environmental impact.
Process Intensification	Optimizing processes for higher efficiency, reducing the overall ecological footprint.

Table 2: Different models and their purpose/scope, strengths and limitations

Model Type	Purpose/Scope	Strengths	Limitations
Life Cycle Assessment (LCA) Models [23]	Assess environmental impact throughout life cycle	Holistic view of environmental impact	Data-intensive, may lack detailed reaction insights
Reaction Kinetics Models [21]	Understand and optimize chemical reaction rates	Optimization of reaction conditions	Focus on kinetics, may not address broader impact
Computational Chemistry Models [24]	Predict electronic structures and reaction mechanisms	Detailed insights into molecular behavior	Computationally intensive, may not scale well
Quantitative Structure-Activity Relationship (QSAR)	Correlate structure with biological/environmental activities	Predict toxicity and activity	Requires extensive experimental data





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Models [51]			
Molecular Dynamics Models [5]	Simulate time-dependent behavior of molecular systems	Insights into molecular interactions	Computationally demanding, may be unnecessary
Chemical Thermodynamics Models [23]	Predict feasibility and spontaneity of chemical reactions	Thermodynamic understanding	May not provide dynamic behavior information
Flux Balance Analysis (FBA) [2,31]	Analyze metabolite flow through biochemical pathways	Systems biology, predictive modeling	Assumes steady-state conditions, simplification
Bayesian Models [47]	Analyze and interpret experimental data in analytical chemistry	Probabilistic inference	Dependence on prior information, complexity
Computational Fluid Dynamics (CFD) Models [1, 37]	Simulate fluid flow and mass transfer in chemical reactors	Reaction engineering, process optimization	Computational complexity, may require detailed data
Quantum Monte Carlo Models [41]	Accurate solutions to Schrödinger equation for complex systems	Quantum chemistry, high accuracy	Computationally expensive, limited to specific systems
Agent-Based Models [6]	Simulate behavior of chemical agents in the environment	Predict fate and transport	Computational complexity, parameterization
Statistical Mechanics Models [43]	Describe statistical distribution of particles in a system	Thermodynamic properties	Limited to equilibrium conditions, may lack dynamics
Process Systems Engineering (PSE) [28]	Optimizing and improve industrial processes through a multidisciplinary approach, utilizing advanced modeling and simulation tools	Comprehensive approach to optimization and efficiency	The complexity of modeling, data requirements, computational intensity, and the need for specialized expertise

Table 3: Application and practical application of various mathematical models in the area of atmospheric chemistry

Model Type	Application	Practical Application
Life Cycle Assessment (LCA) Models	Assessing environmental impact throughout the life cycle.	<ul style="list-style-type: none"> Comparing the environmental impact of two different packaging materials. Determining the ecological footprint of a bio fuel production process.
Reaction Kinetics Models	Optimizing reaction conditions for efficiency and waste reduction.	<ul style="list-style-type: none"> Designing efficient and sustainable chemical reactions. Determining the optimal reaction time, temperature, and catalyst concentration.
Computational Chemistry Models	Predicting molecular structures, properties, and reaction mechanisms.	<ul style="list-style-type: none"> Designing environmentally friendly catalysts. Predicting the properties of green solvents for extraction processes.
QSAR Models	Predicting toxicity or biological activity of chemicals based on structure.	<ul style="list-style-type: none"> Assessing the environmental impact of new pharmaceutical compounds. Designing less toxic pesticides.
Molecular Dynamics	Simulating dynamic behavior of	<ul style="list-style-type: none"> Studying the behavior of green





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Models	molecules to understand interactions.	solvents at the molecular level. <ul style="list-style-type: none"> Investigating the interactions between bio molecules and green catalysts.
Chemical Thermodynamics Models	Predicting the feasibility of chemical reactions under different conditions.	<ul style="list-style-type: none"> Assessing the energy efficiency of a green chemical process. Optimizing reaction conditions to minimize energy input.
Flux Balance Analysis (FBA)	Analyzing the flow of metabolites in biochemical pathways for metabolic engineering.	<ul style="list-style-type: none"> Designing microorganisms for the production of bio-based chemicals. Optimizing metabolic pathways for renewable fuel production.
Bayesian Models	Analyzing and interpreting analytical data with uncertainty quantification.	<ul style="list-style-type: none"> Bayesian analysis of experimental data to determine measurement uncertainty. Assessing the reliability of analytical methods in green chemistry.
Computational Fluid Dynamics (CFD) Models	Simulating fluid flow and mass transfer in chemical reactors.	<ul style="list-style-type: none"> Designing reactors with improved mixing for enhanced reaction efficiency. Optimizing the flow patterns to reduce energy consumption in chemical processes.

Table 4: Real life application of different mathematical models

Mathematical Model	Real-Life Application
Life Cycle Assessment (LCA) Models	Assessing the environmental impact of a biodegradable plastic compared to traditional plastic over its entire life cycle.
Reaction Kinetics Models	Optimizing the reaction conditions for the production of biodiesel to minimize waste and increase efficiency.
Computational Chemistry Models	Designing catalysts for green chemical reactions to reduce energy consumption and enhance selectivity.
QSAR Models	Predicting the toxicity of a new pesticide based on its chemical structure to guide the development of safer alternatives.
Molecular Dynamics Models	Studying the behavior of green solvents at the molecular level to improve their use in extraction processes.
Chemical Thermodynamics Models	Assessing the energy efficiency of a green chemical process by predicting the thermodynamic feasibility of reactions.
Flux Balance Analysis (FBA)	Designing microorganisms for the production of bio-based chemicals by optimizing metabolic pathways.
Bayesian Models	Analyzing experimental data on the concentration of pollutants in water with uncertainty quantification for more reliable environmental risk assessment.
Computational Fluid Dynamics (CFD) Models	Designing reactors with improved mixing for enhanced reaction efficiency in the production of pharmaceuticals.

Table 5: Comparison among LCA, RKM and PSE models

Models →	Life Cycle Assessment(LCA)	Reaction Kinetics Modeling (RKM)	Process Systems Engineering (PSE)
Purpose	LCA is a holistic approach that assesses the environmental	Reaction kinetics modeling focuses on understanding	<ul style="list-style-type: none"> Design, optimize, and control industrial





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	<p>impact of a product or process throughout its entire life cycle, from raw material extraction to disposal.</p>	<p>and predicting the rates of chemical reactions in green processes.</p>	<p>processes for efficiency, safety, and sustainability.</p> <ul style="list-style-type: none"> Integrate principles from engineering, mathematics, and computer science for comprehensive process management. Address complex challenges in chemical, petroleum, and biochemical engineering through systematic methodologies.
Key features	<ul style="list-style-type: none"> Comprehensive and considers multiple environmental aspects (e.g., energy use, resource depletion, emissions). Provides a systematic framework for evaluating sustainability. Considers indirect and cumulative effects. Allows for comparisons between different products or processes. 	<ul style="list-style-type: none"> Specific to chemical reactions and processes. Helps optimize reaction conditions for efficiency and minimal waste. Provides insights into reaction mechanisms. Facilitates the design of green and efficient synthetic routes. 	<ul style="list-style-type: none"> Multidisciplinary integration Systematic design methodologies Utilization of mathematical models Focus on process optimization Implementation of advanced control strategies Incorporation of data-driven decision-making
Mathematical Foundation	<p>LCA involves mathematical modeling and statistical analysis to quantify environmental impacts, often using input-output analysis and system dynamics models.</p>	<p>The mathematical foundation of reaction kinetic modeling involves formulating rate equations to describe the speed and mechanisms of chemical reactions, incorporating factors such as rate constants, order of reaction, and temperature dependency. These equations are used to predict concentration changes over time and optimize reaction</p>	<p>PSE employs mathematical models, often based on chemical engineering principles and differential equations, to simulate and optimize chemical processes. This includes reaction kinetics, thermodynamics, and process integration models.</p>





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		conditions.	
Limitations	<ul style="list-style-type: none"> Requires substantial data and may be data-intensive. Complexity can make it challenging to capture all variables accurately. 	<ul style="list-style-type: none"> May not capture the broader environmental impact beyond the reaction itself. Assumes a closed system, and external factors may be neglected. 	<ul style="list-style-type: none"> Complexity of dealing with intricate systems Dependency on accurate and reliable data High computational costs for advanced strategies Potential inaccuracies due to modeling assumptions Challenges in integrating diverse disciplines and departments

Table 6: Comparison between LCA and RKM on the basis of their scope, complexity and data requirements

Scope	<ul style="list-style-type: none"> LCA has a broader scope, considering the entire life cycle of a product or process 	<ul style="list-style-type: none"> Reaction kinetics modeling focuses specifically on the chemical reactions involved.
Complexity	<ul style="list-style-type: none"> LCA is generally more complex due to the multitude of factors considered. 	<ul style="list-style-type: none"> Reaction kinetics modeling can be more straightforward, especially for well-defined chemical processes.
Data requirements	<ul style="list-style-type: none"> LCA often requires extensive and varied data from different stages of the life cycle. 	<ul style="list-style-type: none"> Reaction kinetics modeling may be less data-intensive for individual reactions but requires accurate kinetic data.

Table 7: Comparison between LCA and PSE on the basis of their scope, complexity and data requirements

	LCA	PSE
Scope	<ul style="list-style-type: none"> LCA has a broader scope, considering the entire life cycle of a product or process. 	<ul style="list-style-type: none"> Focuses on optimizing processes within a system or industrial plant, including design, operation, and control aspects.
Complexity	<ul style="list-style-type: none"> LCA is generally more complex due to the multitude of factors considered. 	<ul style="list-style-type: none"> Can range from simple mass and energy balance calculations to highly complex mathematical models for process optimization and control. Complexity depends on the specific problem being addressed.
Data requirements	<ul style="list-style-type: none"> LCA often requires extensive and varied data from different stages of the life cycle. 	<ul style="list-style-type: none"> Data requirements vary depending on the specific PSE application, but generally involve detailed information on process inputs, outputs, equipment specifications, operating conditions, etc. Data collection may also be resource-intensive but often focuses on a specific process or system.





T2D Digital Twin: GV Analysis to Recommend Meds

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ABSTRACT

Digital twins (DTs) translate a real-world concept into the metaverse through simulation and provide the ability to predict behaviour of the virtual replica using decision models. A DT for healthcare (DTH) is a novel and useful application. This work focuses on the development of a decision-making framework behind a DTH, using Artificial Intelligence (AI) approaches, for providing oral medication (non-insulin hypoglycaemic agent) recommendations for type 2 diabetes mellitus (T2DM) patients. The framework can be used to uncover correlations between blood glucose levels (BGL) and oral diabetes medication by analyzing daily glycaemic variability (GV) in a group of patients. The *Shanghai T2DM* dataset's laboratory measurements and apt continuous glucose monitoring (CGM) readings (for periods of 3–14 days) of 100 T2DM patients was used for the purpose. This system is a promising start for intricate application of DTs in healthcare as a decision-support tool for clinicians and doctors on personalized medication recommendations. The possible limitations and assumptions of such a framework's implementation are also detailed in this work.

Keywords: digital twin framework, healthcare, diabetes management, type-2 diabetes mellitus, Machine Learning (ML)





INTRODUCTION

A digital twin (DT) is a computer-generated replica of a real-world system or structure. DTs can be used for parts, process, or system twinning. Since a simulated model of an entity is easier to manipulate, DTs have found wide-ranging usefulness and are revolutionizing efforts to manage, create, and study systems or processes in many industrial and human spheres like manufacturing, architecture, aerospace, education, and healthcare. With increasing accuracy of Industry 4.0 concepts and analytic ability with AI approaches, it has become clear that a DT can be implemented and personalized to almost any industry and within most scenarios. Type 2 diabetes (T2D) is a chronic human condition characterized by derangements in the secretion and action of the hormone insulin, leading to hyperglycaemia (an increased level of blood sugar). HbA1C levels, showing average blood glucose over a 2- to 3-month period, for diabetic patients are greater than 8% (>183 mg/dl) [1]. Medicines are generally prescribed to maintain a constant level of blood glucose, i.e. without hyper- or hypoglycaemia. Traditionally, oral hypoglycaemic agents (OHAs) and insulin infusion are two widely used approaches in managing T2D. The OHA in the form of pills is recommended for patients who are newly diagnosed or not insulin dependent [2]. The main aim of this work is to use glycaemic variability (GV) to predict oral medication. We also aim to answer the question if GV is a useful characteristic for effect on prescribed medication. Most patients take combination medication for T2D, hence we aim to understand medication and GV correlations for as many medications as possible so that a new patient's data may be predicted with the help of historical data from other patients. While it is acknowledged that a new patient's medication effects cannot be characterized based on other T2D patients' GV alone, this framework would help us understand if the trends of GV are similar in all patients prescribed with similar medications or the DT should be implemented on finer levels of the human body, i.e., simulation of physiological changes at the molecular level to show changes in the BGL for other prescribed medications.

RELATED WORK

With the advent of DT technology in the healthcare field in 2017 and forthcoming years [3], the vast possibility of applying DTs to improve disease management, precision healthcare, and diagnostic ability has been seen [4]. DTs begin with a real-world entity that we wish to simulate and work with, which could be a physical structure like a building or an abstract process. The use of DTs to study biological organisms is increasing in prevalence with research and healthcare facilities using real-time simulation [5] for better understanding and treatment decisions. The healthcare domain has also found DTs to be potentially gamechanging in medical device building and management, disease management, and personalised medicine in the pharmaceutical industry [6]. DTs are a melting point of technological advancements in IoT, Augmented and Virtual Reality (AR/VR), big data analytics, cloud computing, and AI [7]. With the ability to combine vast amounts of heterogeneous data sourced from real-time sensors, DTs are aimed to improve patient experiences in healthcare facilities and help in the decision-making process for professionals. The ability of a DT to handle complex data and possibly replicate a complex system with optimized solutions makes it an attractive investment for most industry experts. In case of T2D, patients and doctors work together to decide on what medication best suits them, but this often takes time. The DT understands a patient's body and predicts their physiological behaviour to other medications by applying different medications to new instances of DTs [8] and analysing the outcomes. This makes it a game-changing technique for drug repurposing and medication prescription in real time. Innovative techniques in diabetes mellitus (DM) management using DTs have made notable progress especially in precision medicine [9,10] and personalised diet and food planning [11].

Digital twin healthcare (DTH) and related characteristics

A digital twin as a replication of a real-world living or non-living entity is expected to collect real-time data from multiple sources, provide concrete simulations of the entity, and predict outcomes or possess decision-making capability regarding behaviour of the entity as close as possible to the real-world. In healthcare, a DT could be designed to simulate the whole human body (whole-body digital twin) of just one biological system or organ



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(disease-specific or organ-specific behaviour) or at finer levels—the molecular or cellular levels. The DTH is considered to have 5 components [4], namely, the physical patient or healthcare-related entity, the virtual patient or model, data belonging to both the physical entity and digital model's analytical results, bidirectionally mapped data, and finally, the functional requirements of the DTH which may include predicting disease progression, disease cause, or operational efficiency for a healthcare system. To obtain data in realtime and with high accuracy, wearable devices are widely used, for instance, continuous BGL tracking is done using the Free Style Libre Pro sensor [12, 13]. Real-time exploratory analysis (EDA) is done with forecasting techniques like multi-variate and multi-time step or time series analysis like the matrix profile-based analysis [13].

Modelling behind a DTH

The structure of a DT generally involves taking a physical entity's data and connecting it to a digital model to analyse and possibly predict how future behaviour of the entity would look like when new real-time data are supplied. To do this, there are multiple assumptions to be made based on the use case and functional requirements of the model. Analytic and data-driven decision-making is a key concept in modelling a DT. Recently, AI approaches with ML and DL models have been gaining popularity for analysis. However, the approach requires a large volume of data from the physical body to train the virtual replication in order to understand nuanced correlations between variables in the human body. A collated list of relevant studies that have previously used Machine Learning (ML) or Deep Learning (DL) algorithms is given in [Table 1](#).

Challenges for a DT in healthcare (DTH)

A DTH would focus on understanding nuances of the human body. Herein lies the greatest difficulty to simulate for a programmed system—the underlying reactions in the human body are often unknown [17] unlike in a mechanical model that can be thoroughly studied and re-created.

Dataset

Data regarding healthcare are subject to high security and ethical standards. To obtain and use real-time data, patients' privacy rights are to be ensured (HIPAA Privacy rule [18]).

Shanghai T2DM dataset

The *Shanghai T2DM* dataset [19] provides valuable assistance with apt laboratory measurements and CGM data for periods of 3–14 days (recorded every 15 minutes) of 100 T2D patients. For the purposes of this work, from the features (Table 2) of the dataset, CGM data and non-insulin hypoglycemic agents were considered as relevant. Additional visualizations and exploratory analyses were also done in order to better understand the dataset. Zhao et al. [19] provide clinical characteristic data range for all numerical variables (also shown in Fig. 1 and other relevant exploratory analysis in Fig. 2, Fig. 3). Patients in the data have a mean age of 60.17 years and mean BMI of 23.69. Shamanna et al. [32] also describe the mean Time-In-Range (TIR) and mean Time-Above-Range (TAR) for the dataset as being at 77.7% and 20%, respectively. It is suggested that glycaemic control can be achieved with predictions of CGM values (ahead in time BGLs) from past values with time series models. The concept behind such an approach is described by Sparacino et al. [20] for type 1 diabetes patients using CGM data measured every 3 minutes and predicting ahead in time glucose levels with neural networks and ARIMA.

Intricacies and Quantification

A DTH would also have to consider multiple affecting variables within the human body. Physiological reactions may not be quantifiable as an equation, but it is possible to train a model to predict the possible trend of a reaction based on the learnings from historical data. Hence, capturing the intricacies of physiological changes greatly depends on the level of personalization required and amount of data fed to the model.

Validation

A healthcare DT would have to be validated by experts or from a database of such knowledge. Since it is not possible to accurately classify the human body's reaction to settings (as psychological and other factors come into play), it is



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necessary for a DTH to regularly be fed with real-time patient values for validation. In development of such a system, it is vital to ensure validation of the AI techniques used and whether the DT is proceeding in the right direction overall.

Use cases**Healthcare services**

Ying et al. [21] describe a cloud-based DT framework (CloudDTH) for elderly healthcare services. The modelling of Cloud DTH is given in 4 stages of modelling, namely, information, sensor, behaviour, and rule modelling. The physical entity data required for such a platform include real-time monitoring with wearable devices, crisis warning, disease diagnosis, medication reminder, and medical treatment plan pathways and management. A detailed case of gene modelling for medication recommendation is given in the study, where the platform uses personal health records and gene types of patients to provide reminders to take medications. Elayan et al. [16] describe a patient DT that reads ECG signals to classify normal and abnormal heart rhythm. A generic DT structure for monitoring the real-time health status and detecting body metrics anomalies was proposed. The neural network algorithm—LSTM showed the best performance among 5 other models (CNN, SVC, LR, LSTM and MLP) used for training in the study. Wang et al. proposed a cloud-based DT storage solution [22] for emergency healthcare services and also identified enabling technologies like the data transmission format, storage file format, AWS services like Kinesis, and IoT Core. The need for compliance with HIPAA regulations was also highlighted.

Hospital

The Pervasive Computing Integrated Discrete Event Simulation [23] is a hospital service DT based on Discrete Event Simulation (DES) with tools like FlexSim integrated with healthcare information systems and Internet of things (IoT) devices. Patient tracks for acute and standard care are simulated and a predictive decision support model is developed. This model enables assessing the efficiency of existing healthcare delivery systems. Real-time input data combined from across care information systems, IoT, and pervasive computing devices is used in this case.

Drug discovery and repurposing

Gary and Chase [17] provide a comprehensive look at a decision-based research framework for creating Drug Development Digital Twins (DDDTs). The flowchart they provided looks at crucial questions to answer behind a DDDT. The framework suggested includes creating the DDDT at the cellular level as it is believed to provide all possible outcomes of using a potential drug on the body. Data collection comments include the need to have provision of data at different biological resolutions in order to preserve the mechanisms of simulating physiological changes. An established or well-known mechanism of a new drug must be simulated. Clinical trials and results have to be iteratively provided for validation. James [8] also comments on the use of DT instances to test individual drug outcomes and in choosing the best path for a patient's data thus making personalized medicine an achievable goal.

Disease specific

Kaul et al. [24] and Jamshidi et al. [25] explore the use of DTs in cancer care. In the work of Kaul et al. [24], the case of endometrial cancer was chosen for study, and the work describes a hypothetical mapping from the manufacturing domain to cancer care for DT creation. A digital model of cancer survivorship along with a particular patient's historical and lab test data would be used to simulate and control to provide cancer diagnosis and treatment pathways. AI algorithms used for such a DT are collated from relevant literature as well. The case of breast cancer is studied in the work of Jamshidi et al. [25] and a DT is implemented with multiple ML models. The dataset is collected from 64 women with breast cancer from the Coimbra Hospital and University Centre (CHUC) during the years 2009 and 2013 along with cancer histology and mammography. Additionally, data from 52 healthy women were obtained as controls. The ML models used included linear regression, decision tree and random forest regression, and gradient boosting algorithms. Gradient boosting provided the best results as per their implementation. DTs for multiple sclerosis have also been explored by Isabel et al. [26] and Jonathan et al. [27] in 2021. Building on this, a DT for patients who experienced an ischemic stroke [28] was tested for disease progression



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using adversarial ML discriminator for clinical measurements and showed the ability of the DT to provide virtually indistinguishable data from real patient data.

A Diabetes DT

Multiple studies have been found relevant to a diabetes DT that uses whole-body digital twin technology [11, 13, 29–32], diabetes remission implementation under the Twin Precision Treatment program [11, 13, 31, 32], and precision nutrition [30]. A DT for discovering alternative carbohydrate/insulin therapies [29] for type 1 diabetic patients by modelling glucose–insulin dynamics was implemented. No similar study for type 2 diabetes has been found so far. Naveenah et al. [33] have recently implemented a DT for chronic kidney disease (CKD—a major complication of T2D) diagnosis using generalized metabolic fluxes (GMFs) and studying microvascular complications leading to CKD.

METHODOLOGY

The T2D DT decision-making framework proposed here is based on learning Glucose Variability (GV). The base of the workflow comes from having a pre-trained model that has the knowledge of other T2D patients' glucose levels and their corresponding prescribed medications. Such a model should have learned patterns and possibly understand the underlying physiological behaviour when medication or meals are taken with variations in glucose levels and should generally compare the BGLs with new input data. In the current framework, raw CGM values (without considering the data as time-series data) are used. This simplistic methodology (Fig. 4) begins with feature engineering and training an ML model on existing T2D patients' BGLs. The *Shanghai T2DM* dataset contains 109 records that include 8 pairs of records from the same patients. All records were used for model training and testing. An approximate 64% of the data (i.e., 70 out of 109 records in the dataset) was used for training the model. The CGM values were extracted into a Pandas Data Frame and fed as an input feature for training a single Random Forest and XGBoost classifier model. The target variables were different OHAs present in the dataset—since a total of 12 OHAs were prescribed, this was a multi-class classification problem. The remaining data (39 out of 109 records) were individually assessed for accuracy against the fitted models and the relevant confusion matrices displayed. Each test file contained different classes to predict which served as a possibly good generalization factor. Some assumptions made are that the files are properly formatted and follow a common schema in all CGM data sheets and that feature engineering and data cleaning are done thoroughly to handle missing data (NaN values and encoding). To validate the system, CGM data from a T2DM patient (using a sensor like the FreeStyle Libre Flash Glucose Monitoring Sensor) and existing medication recommendations (from a qualified doctor) could be used.

ML Algorithms used

Machine Learning algorithms—Random Forest and XGBoost are used to learn patterns in the input CGM data (raw values are provided). Random Forest is a popular supervised machine learning algorithm used for multi-label classification here. It is an ensemble learning (bagging) technique that constructs multiple decision trees for random subsets of the input data and finds the mode of the count of output labels from all decision trees. A graph visualization illustrating working of Random Forest Classifier is shown in Fig. 5. XGBoost is another ensemble learning technique that is also based on decision tree building and the gradient boosting framework. With XGBoost, the algorithm works to correct errors made by previous trees, i.e., combining weak learners to get more accurate predictions. Since the target data here is categorical, we use label encoding to get numeric labels while predicting.

The Python package scikit-learn's Random Forest Classifier and the native XGBoost's XGB Classifier are used.

RESULTS AND DISCUSSION

The proposed methodology for obtaining a pre-trained model proves to have multiple limitations and may not be optimal in providing the whole picture behind physiological changes like GV. As the model's approach is to only



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consider CGM data as training data and the oral medication agents as targets, other important characteristics of patients, like timestamp of medication, mealtimes, BMI of patient, their existing conditions, and variations in GV with reference to other medications taken, are not weighted into the model's training. The Random Forest and XGBoost models overfit to the values (giving test accuracies between 96% and 100%) while also being biased (often tend to prescribe the same medication, as in Fig. 6). It was seen that boundaries for both XGBoost and Random Forest classifiers coincide which suggests that the data give similar learning patterns for decision tree-based ensemble techniques. The possible reasons for this overfitting are discussed. The high training and test accuracies may be attributed to the data being not imputed for class imbalances (as in Fig. 7). Hence, it is seen that Metformin having the most occurrence as an OHA (47 out of 124) than any other in the dataset leads to a clear bias in prediction. A limited number of OHAs (12) are available within the data (as in Fig. 8). Apart from this, 100 recorded patients did not all take OHAs. The EDA shows that commonly available Insulin injection solution combinations (Gansulin R, Novolin R, insulin degludec, insulin aspart (50-50), insulin glulisine, Humulin (70-30), insulin glargine, insulin as part (70-30), Gansulin 40R, Humulin R, Novolin 30R, insulin detemir, insulin glargine) are prescribed in place of OHA (as in Fig. 9), hence reducing the relevant data for the purposes of this work. Due to data sparsity, it is difficult to judge the GV pattern learning and matching as a suitable approach for medication prediction although it can be said that CGM data and GV variation is a definite factor for medication prescriptions.

CONCLUSION AND FUTURE WORK

The approach here must be extended to understand how other agents and comorbidities affect a patient's GV (combination medication prediction is yet to be explored). The approach must also view the significance of glucose variations before and after medication intake (like a windowed GV analysis considering timestamps). The ML models' hyper parameters can be tuned for slightly better results. A personalized learning framework may be developed from here, as the CGM data can be cumulatively used for a particular patient's BGL changes over 3- or 4-month periods to better predict medications. This approach is novel in its use of correlations of glucose variations in multiple T2D patients to possibly predict a new T2D patient's medication. It is worth noting that the approach connects with drug-drug and drug-disease interactions and can be extended for a more comprehensive DT framework in drug repurposing and discovery.

REFERENCES

1. Centers for Disease Control and Prevention. "All About Your A1C." 21 Aug. 2018, Accessed 1 March 2024, www.cdc.gov/diabetes/managing/managing-blood-sugar/a1c.html.
2. Cheng, Alice Y Y, and I George Fantus. "Oral antihyperglycemic therapy for type 2 diabetes mellitus." *CMAJ: Canadian Medical Association journal = journal de l'Association medicale canadienne* vol. 172,2 (2005): 213-26. doi:10.1503/cmaj.1031414
3. T. Erol, A. F. Mendi and D. Doğan, "The Digital Twin Revolution in Healthcare," 2020 4th International Symposium on Multidisciplinary Studies and Innovative Technologies (ISMSIT), Istanbul, Turkey, 2020, pp. 1-7, doi: 10.1109/ISMSIT50672.2020.9255249.
4. Hassani H, Huang X, MacFeely S. "Impactful Digital Twin in the Healthcare Revolution. *Big Data and Cognitive Computing*." 2022; 6(3):83. <https://doi.org/10.3390/bdcc6030083>.
5. Armeni, Patrizio et al. "Digital Twins in Healthcare: Is It the Beginning of a New Era of Evidence-Based Medicine? A Critical Review." *Journal of personalized medicine* vol. 12,8 1255. 30 Jul. 2022, doi:10.3390/jpm12081255
6. Kamel Boulos, Maged N., and Peng Zhang. 2021. "Digital Twins: From Personalised Medicine to Precision Public Health" *Journal of Personalized Medicine* 11, no. 8: 745. <https://doi.org/10.3390/jpm11080745>
7. Kaur, M.J., Mishra, V.P., Maheshwari, P. (2020). "The Convergence of Digital Twin, IoT, and Machine Learning: Transforming Data into Action." In: Farsi, M., Daneshkhan, A., Hosseinian-Far, A., Jahankhani, H. (eds) *Digital*





Vaishnavi Anand and Karthika

- Twin Technologies and Smart Cities. Internet of Things. Springer, Cham. https://doi.org/10.1007/978-3-030-18732-3_1.
8. L. James, "Digital twins will revolutionise healthcare: Digital twin technology has the potential to transform healthcare in a variety of ways – improving the diagnosis and treatment of patients, streamlining preventative care and facilitating new approaches for hospital planning," in *Engineering & Technology*, vol. 16, no. 2, pp. 50-53, March 2021, doi: 10.1049/et.2021.0210.
 9. Chu Yanting, Li Shanhong, Tang Jie, Wu Huiqun. "The potential of the Medical Digital Twin in diabetes management: a review." *Frontiers in Medicine*, Vol. 10, 2023. <https://www.frontiersin.org/articles/10.3389/fmed.2023.1178912>. doi: 10.3389/fmed.2023.1178912.
 10. Y. Liu et al., "A Novel Cloud-Based Framework for the Elderly Healthcare Services Using Digital Twin," in *IEEE Access*, vol. 7, pp. 49088-49101, 2019, doi: 10.1109/ACCESS.2019.2909828.
 11. Shamanna, P., Joshi, S., Shah, L. et al. "Type 2 diabetes reversal with digital twin technology-enabled precision nutrition and staging of reversal: a retrospective cohort study." *Clin Diabetes Endocrinol* 7, 21 (2021). <https://doi.org/10.1186/s40842-021-00134-7>
 12. Thamotharan, Padmapritha, Seshadhri Srinivasan, JothydevKesavadev, Gopika Krishnan, Viswanathan Mohan, Subathra Seshadhri, Korkut Bekiroglu, and Chiara Toffanin. 2023. "Human Digital Twin for Personalized Elderly Type 2 Diabetes Management" *Journal of Clinical Medicine* 12, no. 6: 2094. <https://doi.org/10.3390/jcm12062094>
 13. Shamanna, P., Dharmalingam, M., Sahay, R. et al. Retrospective study of glycemic variability, BMI, and blood pressure in diabetes patients in the Digital Twin Precision Treatment Program. *Sci Rep* 11, 14892 (2021). <https://doi.org/10.1038/s41598-021-94339-6>
 14. Al-Zyoud, Izaldeen, FedwaLaamarti, Xiacong Ma, Diana Tobón, and Abdulmotaleb El Saddik. 2022. "Towards a Machine Learning-Based Digital Twin for Non-Invasive Human Bio-Signal Fusion" *Sensors* 22, no. 24: 9747. <https://doi.org/10.3390/s22249747>
 15. Chenyu Tang, Wentian Yi, Edoardo Occhipinti, Yanning Da, Shuo Gao, Luigi G. Occhipinti. 2023, "Human Body Digital Twin: A Master Plan". arXiv:2307.09225. <https://doi.org/10.48550/arXiv.2307.09225>
 16. H. Elayan, M. Aloqaily and M. Guizani, "Digital Twin for Intelligent Context-Aware IoT Healthcare Systems," in *IEEE Internet of Things Journal*, vol. 8, no. 23, pp. 16749-16757, 1 Dec.1, 2021, doi: 10.1109/JIOT.2021.3051158.
 17. An Gary, Cockrell Chase. 2022. "Drug Development Digital Twins for Drug Discovery, Testing and Repurposing: A Schema for Requirements and Development." *Frontiers in Systems Biology*, Vol. 2, doi: 10.3389/fsysb.2022.928387
 18. Rights, Office for Civil. "The HIPAA Privacy Rule." HHS.gov, 31 Mar. 2022, www.hhs.gov/hipaa/for-professionals/privacy/index.html#:~:text=The%20HIPAA%20Privacy%20Rule%20establishes,care%20providers%20that%20conduct%20certain.
 19. Zhao, Q., Zhu, J., Shen, X. et al. "Chinese diabetes datasets for data-driven machine learning." *Sci Data* 10, 35 (2023). <https://doi.org/10.1038/s41597-023-01940-7>.
 20. G. Sparacino, F. Zanderigo, S. Corazza, A. Maran, A. Facchinetti and C. Cobelli, "Glucose Concentration can be Predicted Ahead in Time From Continuous Glucose Monitoring Sensor Time-Series," in *IEEE Transactions on Biomedical Engineering*, vol. 54, no. 5, pp. 931-937, May 2007, doi: 10.1109/TBME.2006.889774.
 21. Ying, Liu & Zhang, Lin & Yang, Yuan & Zhou, Longfei & Ren, Lei & Wang, Fei & Liu, Rong & Pang, Zhibo & Deen, M.J. (2019). "A Novel Cloud-Based Framework for the Elderly Healthcare Services Using Digital Twin." *IEEE Access*. 7. 49088-49101. 10.1109/ACCESS.2019.2909828.
 22. E. Wang, P. Tayebi and Y.-T. Song, "Cloud-based Digital Twins Storage in Emergency Healthcare," 2023 *IEEE/ACIS 21st International Conference on Software Engineering Research, Management and Applications (SERA)*, Orlando, FL, USA, 2023, pp. 331-335, doi: 10.1109/SERA57763.2023.10197705.
 23. A. Karakra, F. Fontanili, E. Lamine, J. Lamothe and A. Taweel, "Pervasive Computing Integrated Discrete Event Simulation for a Hospital Digital Twin," 2018 *IEEE/ACS 15th International Conference on Computer Systems and Applications (AICCSA)*, Aqaba, Jordan, 2018, pp. 1-6, doi: 10.1109/AICCSA.2018.8612796.





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10. 24. Rohit Kaul, Chinedu Ossai, Abdur Rahim Mohammad Forkan, Prem Prakash Jayaraman, John Zelcer, Stephen Vaughan, Nilmini Wickramasinghe. "The Role of AI for developing digital twins in healthcare: The case of cancer care." 2022 WIREs Data Mining and Knowledge Discovery, Vol. 13, Issue 1. <https://doi.org/10.1002/widm.1480>
11. 25.M. B. Jamshidi, M. Ebadpour and M. M. Moghani, "Cancer Digital Twins in Metaverse," 2022 20th International Conference on Mechatronics - Mechatronika (ME), Pilsen, Czech Republic, 2022, pp. 1-6, doi: 10.1109/ME54704.2022.9983328.
12. 26.Voigt Isabel, Inojosa Hernan, Dillenseger Anja, Haase Rocco, Akgün Katja, ZiemssenTjalf. "Digital Twins for Multiple Sclerosis." 2021 Frontiers in Immunology, Vol. 12. doi: 10.3389/fimmu.2021.669811
13. 27.Jonathan R. Walsh and Aaron M. Smith and Yannick Pouliot and David Li-Bland and Anton Loukianov and Charles K. Fisher. "Generating Digital Twins with Multiple Sclerosis Using Probabilistic Neural Networks." 2020. arXiv:2002.02779.
14. 28.Allen, Angier, Anna Siefkas, Emily Pellegrini, Hoyt Burdick, Gina Barnes, Jacob Calvert, Qingqing Mao, and Ritankar Das. 2021. "A Digital Twins Machine Learning Model for Forecasting Disease Progression in Stroke Patients" Applied Sciences 11, no. 12: 5576. <https://doi.org/10.3390/app11125576>
15. 29.G. Cappon, M. Vettoretti, G. Sparacino, S. D. Favero and A. Facchinetti, "ReplayBG: A Digital Twin-Based Methodology to Identify a Personalized Model From Type 1 Diabetes Data and Simulate Glucose Concentrations to Assess Alternative Therapies," in IEEE Transactions on Biomedical Engineering, vol. 70, no. 11, pp. 3227-3238, Nov. 2023, doi: 10.1109/TBME.2023.3286856.
16. 30.A. M. Vaskovsky, M. S. Chvanova and M. B. Rebezov, "Creation of digital twins of neural network technology of personalization of food products for diabetics," 2020 4th Scientific School on Dynamics of Complex Networks and their Application in Intellectual Robotics (DCNAIR), Innopolis, Russia, 2020, pp. 251-253, doi: 10.1109/DCNAIR50402.2020.9216776.
17. 31.Shamanna, P., Saboo, B., Damodharan, S. et al. "Reducing HbA1c in Type 2 Diabetes Using Digital Twin Technology-Enabled Precision Nutrition: A Retrospective Analysis. " Diabetes Ther 11, 2703–2714 (2020). <https://doi.org/10.1007/s13300-020-00931-w>
18. 32.Shamanna, P., Joshi, S., Shah, L., Dharmalingam, M., Vadavi, A., Damodaran, S., Mohammed, J., Mohamed, M., Poon, T., Keshavamurthy, A., Thajudeen, M., Bhonsley, S. CORRELATION OF DIABETES REMISSION WITH REDUCTIONS IN BLOOD PRESSURE AND CARDIOVASCULAR RISK SCORES: RESULTS OF SIX MONTHS OF RANDOMISED TRIAL WITH DIGITAL TWIN TECHNOLOGY. Journal of Hypertension 40(Suppl 1):p e75-e76, June 2022. | DOI: 10.1097/01.hjh.0000835932.52938.30
19. 33.Naveenah U.S., Arsen B., Andrew W., Wen B.L., Yan S., Yong M. B., Rinkoo D. "A digital twin model incorporating generalized metabolic fluxes to predict chronic kidney disease in type 2 diabetes mellitus." medRxiv 2023.09.22.23295944 [Preprint]. 24 September 2023 [cited 4 Mar 2024]. doi: <https://doi.org/10.1101/2023.09.22.23295944>.

Table 1. Studies Showing MI/DI Modeling For A Dt

Literature	Data used	ML/DL algorithm used
[14]	set of raw time-series data files in "csv" format and the outputs are three engineered raw datasets (i.e., VIPL, COHFACE, and our lab dataset)	MLP, XGBoost, LSTM
[13]	fasting blood draws data, heart rate, sleep parameters, other fitness parameters, blood pressure, weight, blood beta-hydroxybutyrate (BHB), Continuous Glucose Monitor (CGM) data, food intake	gradient boosted decision trees, deep learning neural networks, and long short-term memory models
[15]	No specific use case described	Self-supervised Learning (SSL) algorithms, Recurrent Neural Networks (RNN), Long Short-Term Memory (LSTM), and Transformer networks and explainable AI





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[12]	vital signs, blood glucose levels, or other physical data about the patient	RNN and LSTM for BGL forecasting
[16]	based on the MIT-BIH Arrhythmia Database	convolutional neural network (CNN), multilayer perceptron (MLP), logistic regression (LR), long short-term memory network (LSTM), and support vector classification (SVC)

Table 2. A Quick Look at Features in the Shanghai T2dm Dataset

Laboratory measurements	Clinical Characteristics
Fasting glucose/C-peptide/insulin	Patient ID
Postprandial plasma glucose/C-peptide/insulin	Gender
HbA1c	Age
Glycated Albumin	Height
Total cholesterol	Weight
High-density & Low-density lipoprotein cholesterol	BMI
Creatinine	Smoking and Drinking history
Triglyceride	Type of Diabetes
Estimated Glomerular Filtration rate	Duration of diabetes (years)
Uric Acid	Diabetic complications
Blood urea nitrogen	Comorbidities

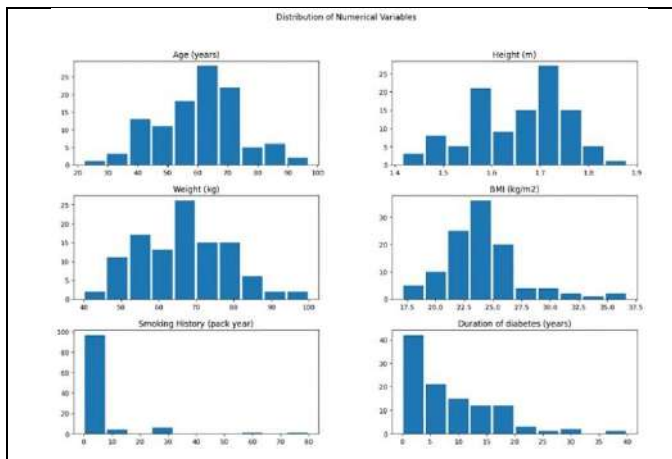


Fig. 1. Histograms showing distribution of numerical variables in dataset

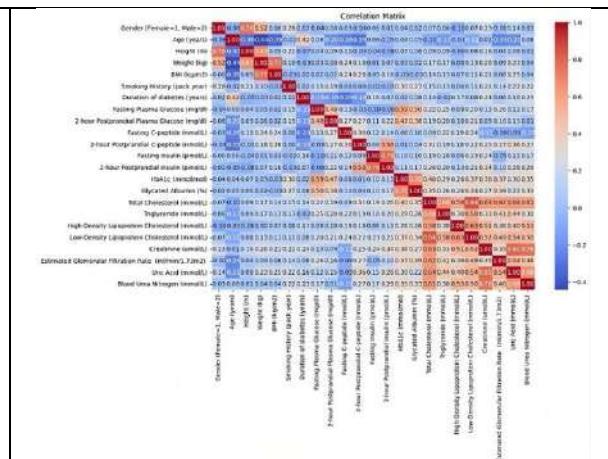


Fig. 2. Correlation matrix between all laboratory measurements in Shanghai T2DM dataset (notice a moderately high correlation between HbA1C levels and fasting plasma glucose, 2-hour postprandial plasma glucose as well as glycated albumin)





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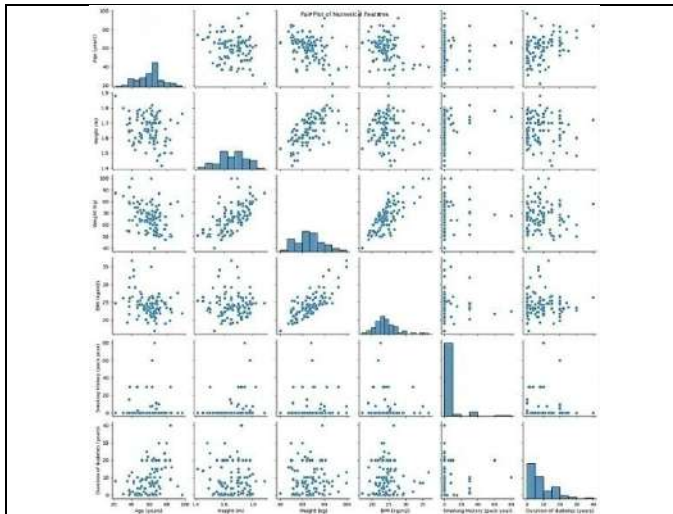


Fig. 3. Pairplots for numerical variables shows positive correlation between weight, height and BMI

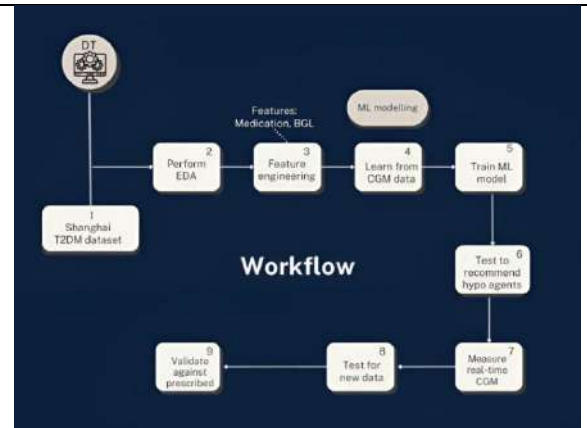


Fig. 4. Current workflow

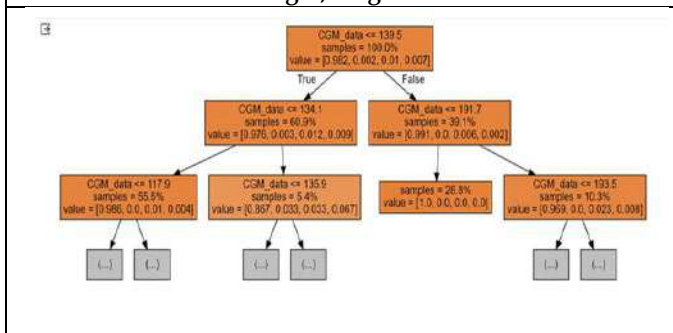


Fig. 5. Example visualization of one constructed decision tree by Random Forest Classifier in current implementation

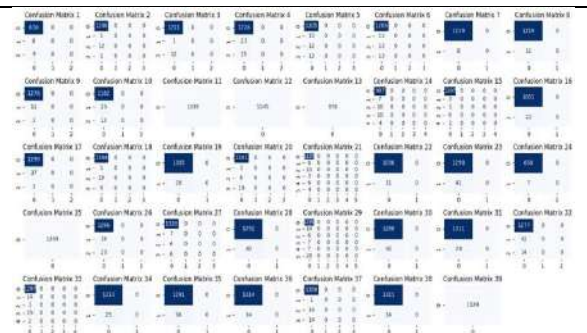


Fig. 6. Confusion matrices for Random Forest classifier—each of 39 test files shows overfitting and bias

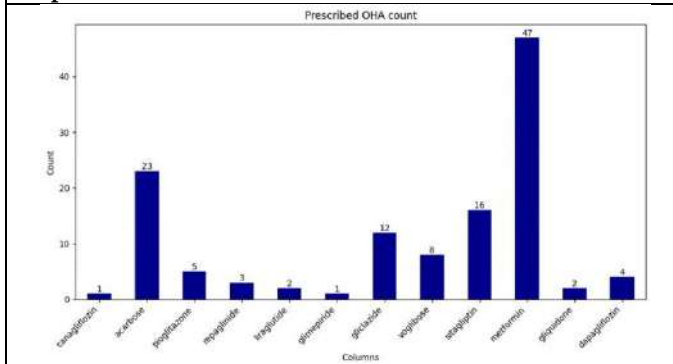


Fig. 7. OHA counts showing class imbalance in the dataset (~37.9% patients given metformin as an OHA)



Fig. 8. List of OHA found in dataset





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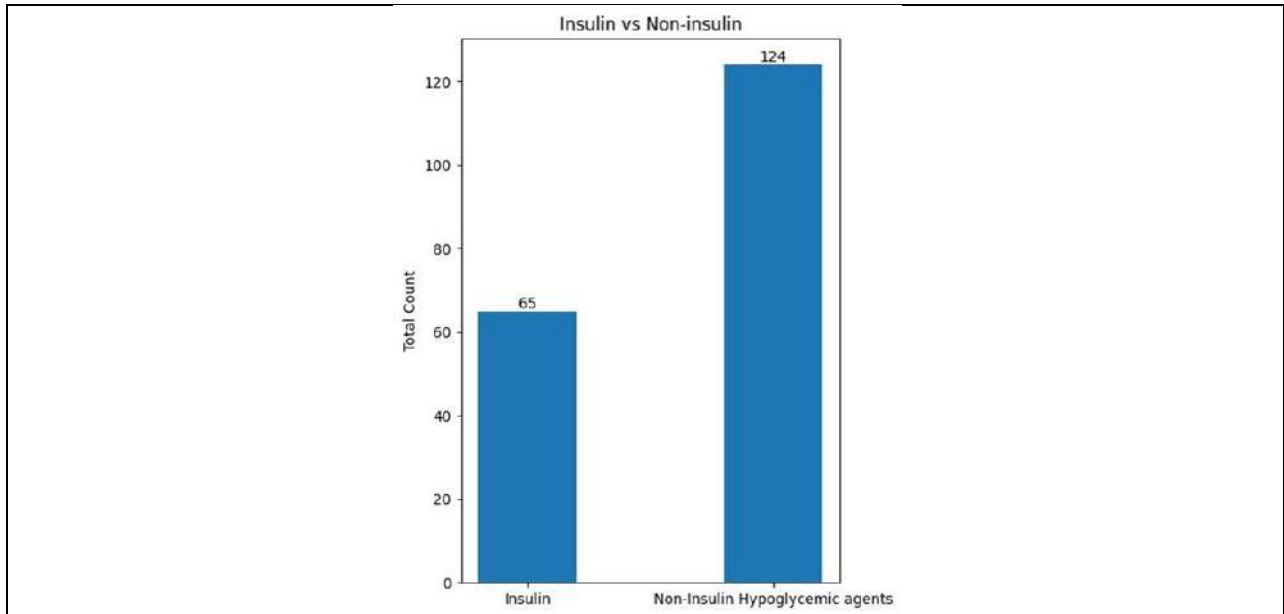


Fig. 9. Bar plot showing number of people prescribed with insulin vs OHAs (the total count exceeds 109 as combination medication is prescribed for most patients—either given more than one insulin solution or more than one OHA)





Pythagorean Intuitionistic and Pythagorean Interval-Valued Intuitionistic Fuzzy Graph

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ABSTRACT

The new interpretation of Pythagorean intuitionistic fuzzy graph (PIFG) and Pythagorean interval-valued intuitionistic fuzzy graph (PIVIFG) were hypothesized in this paper. Pythagorean Intuitionistic fuzzy graph (PIFG) is a generalization of Intuitionistic fuzzy graph with the condition $0 \leq \mathfrak{T}_2(a_i a_j) + \mathfrak{F}_2(a_i a_j) \leq 2$ where and \mathfrak{F} denotes the truth - membership and falsity - membership of x of \mathbb{A} and it can be read as Fraktur T and Fraktur F. Pythagorean interval-valued intuitionistic fuzzy graph (PIVIFG) is a generalization of a Pythagorean interval-valued fuzzy graph with dependent interval-valued intuitionistic components and a Pythagorean interval-valued fuzzy set with condition $0 \leq \mathfrak{T}_{AU}(x)^2 + \mathfrak{F}_{AU}(x)^2 \leq 2$. The primary goal of this article is to apply intuitionistic to Pythagorean fuzzy graphs and Pythagorean interval-valued fuzzy graphs. As a result, we expand a portion of the essential highlights of the PIVIFG along with a few exemplifications.

Keywords: Pythagorean, interval-valued, intuitionistic graph.





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INTRODUCTION

The rapidly expanding field of fuzzy sets published by L.A.Zadeh in 1965[9] paves the way for various applications through fuzzy graphs. It has the power to produce an intuitionistic fuzzy set with the restriction that the totality of membership and non-membership must not exceed 1, which Krassimir Atanassov introduced in 1999[3]. In recent development, the focus of interest is on Pythagorean fuzzy sets by Yager [8] with the constraint that their square sum is less than or equal to 1. The basic concepts of Pythagorean fuzzy sets addressed the Pythagorean fuzzy graph. The mathematical concept that combines fuzzy intuitionistic sets and Pythagorean fuzzy sets is accommodated in Pythagorean intuitionistic fuzzy sets which induce the truth and falsity membership. This set provides a massive information on Pythagorean intuitionistic fuzzy graphs. This generates the idea of the Pythagorean intuitionistic fuzzy set(PIFS). The Pythagorean intuitionistic fuzzy graph was constructed using PIFS. The earliest kind of Pythagorean intuitionistic fuzzy graph is generalized to Pythagorean interval-valued intuitionistic fuzzy graph. This explores the existence of a Pythagorean interval-valued intuitionistic fuzzy graph.

Pythagorean Intuitionistic Fuzzy graph (PIFG) &Pythagorean Interval-Valued Intuitionistic Fuzzy Graph (PIVIFG)

In this part we characterize the Pythagorean Intuitionistic fuzzy set (PIFS), Pythagorean Intuitionistic fuzzy graph(PIFG), Pythagorean Interval-valued Intuitionistic fuzzy set(PIVIFS), and Pythagorean Interval-valued Intuitionistic fuzzy graph(PIVIFG) and a portion of their properties.

Definition 2.1:

A **Pythagorean Intuitionistic fuzzy set (PIFS)** A in \mathbb{E} is defined as an object of the following type $A = \{ \langle a_i, \mathfrak{T}_A(a_i), \mathfrak{F}_A(a_i) \rangle / a_i \in \mathbb{E} \}$ Where the functions $\mathfrak{T}_A : \mathbb{E} \rightarrow [0,1]$ and $\mathfrak{F}_A : \mathbb{E} \rightarrow [0,1]$ define the degree of truth membership and falsity membership of the element $a \in \mathbb{E}$ respectively and for every $a_i \in \mathbb{E}$, $0 \leq \mathfrak{T}_A(a_i) + \mathfrak{F}_A(a_i) \leq 1$ and $0 \leq \mathfrak{T}_A^2(a_i) + \mathfrak{F}_A^2(a_i) \leq 2$.

Definition 2.2

$G=(\mathbb{V},\mathbb{E})$ is a **Pythagorean Intuitionistic Fuzzy Graph (PIFG)** with \mathfrak{T}_1 and \mathfrak{F}_1 from \mathbb{V} to $[0,1]$ signifying truth membership, falsity membership functions of \mathbb{V} and $0 \leq \mathfrak{T}_1(a_i) + \mathfrak{F}_1(a_i) \leq 1$ for all $a_i \in \mathbb{V}$ such that $\mathfrak{T}_2(a_i a_j) \leq \mathfrak{T}_1(a_i) \wedge \mathfrak{T}_1(a_j)$, $\mathfrak{F}_2(a_i a_j) \geq \mathfrak{F}_1(a_i) \vee \mathfrak{F}_1(a_j)$. where $\mathfrak{T}_2, \mathfrak{F}_2$ from $\mathbb{V} \times \mathbb{V}$ to $[0,1]$ stand for the truth membership, falsity membership functions of \mathbb{E} , with $0 \leq \mathfrak{T}_2^2(a_i a_j) + \mathfrak{F}_2^2(a_i a_j) \leq 2$ and $0 \leq \mathfrak{T}_2(a_i a_j) + \mathfrak{F}_2(a_i a_j) \leq 1$ for all $a_i a_j \in \mathbb{E}$.

Example 2.3

The Figure 1 is a model for PIFG

Definition 2.4

$G=(\mathbb{V},\mathbb{E})$ is a PIFG. Subsequently, the aggregate of the truth and falsity membership of each one of the incident edges with the vertex $a_i \in \mathbb{V}$ is called the degree of the vertex $a_i \in \mathbb{V}$ and it is indicated by $\mathfrak{d}(a_i)$

Defintion 2.5

$\mathfrak{N}(G)$ indicates the minimum degree of PIFG and it is determined by the lowest truth and lowest falsity membership value in each vertex's degree across the whole graph.

Definition 2.6

$\mathfrak{M}(G)$ indicates the maximum degree of PIFG and it is determined by the highest truth and highest falsity membership value in each vertex's degree across the whole graph.





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Exampel2.7

Consider the Figure 1
 $\check{d}(a_1) = \langle 0.2, 1.6 \rangle$ $\check{d}(a_2) = \langle 0.3, 1.5 \rangle$ $\check{d}(a_3) = \langle 0.3, 1.7 \rangle$
 $\aleph(G) = \langle 0.2, 1.5 \rangle$ $\beth(G) = \langle 0.3, 1.7 \rangle$

Definition 2.8

A **Pythagorean Interval-valued Intuitionistic fuzzy set (PIVIFS)** A in E is defined as an object of the following form
 $A = \{ \langle a, [\mathfrak{I}_{AL}(a), \mathfrak{I}_{AU}(a)], [\mathfrak{F}_{AL}(a), \mathfrak{F}_{AU}(a)] \rangle / a \in E \}$
 Where the functions $\mathfrak{I}_{AL} : E \rightarrow [0,1]$, $\mathfrak{I}_{AU} : E \rightarrow [0,1]$, $\mathfrak{F}_{AL} : E \rightarrow [0,1]$ and $\mathfrak{F}_{AU} : E \rightarrow [0,1]$ define the degree of truth membership and falsity membership of the element $a \in E$ respectively and for every $a \in E$, $0 \leq \mathfrak{I}_{AU}(a) + \mathfrak{F}_{AU}(a) \leq 1$ and $0 \leq \mathfrak{I}_{AU}^2(a) + \mathfrak{F}_{AU}^2(a) \leq 2$.

Definition 2.9

$G = (A, B)$ is a **Pythagorean interval-valued intuitionistic fuzzy graph(PIVIFG)** of a graph $G^* = (V, E)$ which is a crisp graph. Where $A = \langle [\mathfrak{I}_{AL}, \mathfrak{I}_{AU}], [\mathfrak{F}_{AL}, \mathfrak{F}_{AU}] \rangle$ is an interval-valued intuitionistic set on V and $B = \langle [\mathfrak{I}_{BL}, \mathfrak{I}_{BU}], [\mathfrak{F}_{BL}, \mathfrak{F}_{BU}] \rangle$ is an interval-valued intuitionistic relation on E meeting the requirements listed below:
 (i) $V = \{a_1, a_2, \dots, a_n\}$, such that $\mathfrak{I}_{AL} : V \rightarrow [0, 1]$, $\mathfrak{I}_{AU} : V \rightarrow [0, 1]$, and $\mathfrak{F}_{AL} : V \rightarrow [0, 1]$, $\mathfrak{F}_{AU} : V \rightarrow [0, 1]$ denote the degree of truth membership, and degree of falsity membership of the element $a_i \in V$, respectively, and $0 \leq \mathfrak{I}_{AU}(a_i) + \mathfrak{F}_{AU}(a_i) \leq 1$ for all $a_i \in V$ ($i=1, 2, \dots, n$)
 (ii) The functions $\mathfrak{I}_{BL} : V \times V \rightarrow [0, 1]$, $\mathfrak{I}_{BU} : V \times V \rightarrow [0, 1]$, $\mathfrak{F}_{BL} : V \times V \rightarrow [0, 1]$ and $\mathfrak{F}_{BU} : V \times V \rightarrow [0, 1]$ are such that $\mathfrak{I}_{BL}(\{a_i, a_j\}) \leq \min [\mathfrak{I}_{AL}(a_i), \mathfrak{I}_{AL}(a_j)]$, $\mathfrak{I}_{BU}(\{a_i, a_j\}) \leq \min [\mathfrak{I}_{AU}(a_i), \mathfrak{I}_{AU}(a_j)]$, $\mathfrak{F}_{BL}(\{a_i, a_j\}) \geq \max [\mathfrak{F}_{AL}(a_i), \mathfrak{F}_{AL}(a_j)]$, $\mathfrak{F}_{BU}(\{a_i, a_j\}) \geq \max [\mathfrak{F}_{AU}(a_i), \mathfrak{F}_{AU}(a_j)]$, denoting the degree of truth-membership, falsity- membership of the edge $(v_i, v_j) \in E$ respectively, where $0 \leq \mathfrak{I}_{BU}(\{a_i, a_j\}) + \mathfrak{F}_{BU}(\{a_i, a_j\}) \leq 1$ for all $\{a_i, a_j\} \in E$ ($i, j = 1, 2, \dots, n$) and $0 \leq (\mathfrak{I}_{BU}(a_i, a_j))^2 + (\mathfrak{F}_{BU}(a_i, a_j))^2 \leq 2 \forall (a_i, a_j) \in E$. Here A refers as Pythagorean interval-valued intuitionistic vertex set of V and B as Pythagorean interval-valued intuitionistic edge set of E respectively.

Example 2.10

The Figure 2 is an example for PIVIFG

Definition 2.11

The degree of the vertex, minimum and maximum degree of the PIVIFG is found as usual like PIFG.

Example 2.12

Consider the Figure 2
 $\check{d}(a_1) = \langle [0.2, 0.8], [0.8, 1.1] \rangle$ $\check{d}(a_2) = \langle [0.2, 0.9], [0.7, 0.9] \rangle$
 $\check{d}(a_3) = \langle [0.2, 0.6], [0.9, 1.2] \rangle$ $\check{d}(a_4) = \langle [0.2, 0.7], [0.8, 1] \rangle$
 $\aleph(G) = \langle [0.2, 0.6], [0.7, 0.9] \rangle$ $\beth(G) = \langle [0.2, 0.9], [0.9, 1.2] \rangle$

Proposition 2.13

A Pythagorean interval-valued intuitionistic fuzzy graph is the generalization of interval-valued fuzzy graph.

Proof

Assume $G = (A, B)$ be a PIVIFG.
 In the vertex and edge set take the membership value of falsity as zero.
 Then it will reduce to anIVFG.





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Example 2.14

Consider Figure 3, a PIVIFG with 3 vertices
 Presently taking the falsity – membership values of the vertex set and edge set as 0.
 At this junctures, the schematic above will turn into Figure 4 a IVFG.

Proposition 2.15

A Pythagorean Interval-valued intuitionistic fuzzy graph (PIVIFG) is the generalization of the Pythagorean intuitionistic fuzzy graph (PIFG).

Proof

Presume $G = (A, \mathbb{B})$ is a Pythagorean interval-valued intuitionistic fuzzy graph (PIVIFG).
 Among the vertex and edge set take the membership value of upper limit in truth and falsity membership as zero.
 Then PIVIFG reduces to PIFG

Proposition 2.16

In a PIVIFG, the sum of all vertex degrees of truth membership is twice the sum of all edge degrees of truth membership.

$$\begin{aligned} \text{(i.e.) } \sum \check{d}(a_i) &= (\sum \check{d}_{\mathcal{T}}(a_i), \sum \check{d}_{\mathcal{F}}(a_i)) \\ &= (2[\sum_{a_i \neq a_j} \mathcal{T}_{\mathbb{B}L}(a_i, a_j), \sum_{a_i \neq a_j} \mathcal{T}_{\mathbb{B}U}(a_i, a_j)], \\ &\quad 2[\sum_{a_i \neq a_j} \mathcal{F}_{\mathbb{B}L}(a_i, a_j), \sum_{a_i \neq a_j} \mathcal{F}_{\mathbb{B}U}(a_i, a_j)]) \end{aligned}$$

The same is true for the membership values of degrees in falsity.

Proof

Let $G = (A, \mathbb{B})$ be PIVIFG where V is a vertex set with elements $a_1, a_2, a_3, \dots, a_n$.

$$\begin{aligned} \sum \check{d}(a_i) &= (\sum \check{d}_{\mathcal{T}}(a_i), \sum \check{d}_{\mathcal{F}}(a_i)) \\ &= (\sum [\check{d}_{\mathcal{T}_L}(a_i), \check{d}_{\mathcal{T}_U}(a_i)], \sum [\check{d}_{\mathcal{F}_L}(a_i), \check{d}_{\mathcal{F}_U}(a_i)]) \\ &= ([\check{d}_{\mathcal{T}_L}(a_1), \check{d}_{\mathcal{T}_U}(a_1)], [\check{d}_{\mathcal{F}_L}(a_1), \check{d}_{\mathcal{F}_U}(a_1)]) + \\ &\quad ([\check{d}_{\mathcal{T}_L}(a_2), \check{d}_{\mathcal{T}_U}(a_2)], [\check{d}_{\mathcal{F}_L}(a_2), \check{d}_{\mathcal{F}_U}(a_2)]) + \dots + \\ &\quad ([\check{d}_{\mathcal{T}_L}(a_n), \check{d}_{\mathcal{T}_U}(a_n)], [\check{d}_{\mathcal{F}_L}(a_n), \check{d}_{\mathcal{F}_U}(a_n)])) \\ &= ([\sum_{a_1 \neq a_j} \mathcal{T}_{\mathbb{B}L}(a_1, a_j), \sum_{a_1 \neq a_j} \mathcal{T}_{\mathbb{B}U}(a_1, a_j)], [\sum_{a_1 \neq a_j} \mathcal{F}_{\mathbb{B}L}(a_1, a_j), \sum_{a_1 \neq a_j} \mathcal{F}_{\mathbb{B}U}(a_1, a_j)]) + \\ &([\sum_{a_2 \neq a_j} \mathcal{T}_{\mathbb{B}L}(a_2, a_j), \sum_{a_2 \neq a_j} \mathcal{T}_{\mathbb{B}U}(a_2, a_j)], [\sum_{a_2 \neq a_j} \mathcal{F}_{\mathbb{B}L}(a_2, a_j), \sum_{a_2 \neq a_j} \mathcal{F}_{\mathbb{B}U}(a_2, a_j)]) \\ &\quad + \dots + ([\sum_{a_n \neq a_j} \mathcal{T}_{\mathbb{B}L}(a_n, a_j), \sum_{a_n \neq a_j} \mathcal{T}_{\mathbb{B}U}(a_n, a_j)], \\ &[\sum_{a_n \neq a_j} \mathcal{F}_{\mathbb{B}L}(a_n, a_j), \sum_{a_n \neq a_j} \mathcal{F}_{\mathbb{B}U}(a_n, a_j)]) \\ &= ([\mathcal{T}_{\mathbb{B}L}(a_1, a_2), \mathcal{T}_{\mathbb{B}U}(a_1, a_2)], [\mathcal{F}_{\mathbb{B}L}(a_1, a_2), \mathcal{F}_{\mathbb{B}U}(a_1, a_2)]) \\ &+ ([\mathcal{T}_{\mathbb{B}L}(a_1, a_3), \mathcal{T}_{\mathbb{B}U}(a_1, a_3)], [\mathcal{F}_{\mathbb{B}L}(a_1, a_3), \mathcal{F}_{\mathbb{B}U}(a_1, a_3)]) + \dots + \\ &([\mathcal{T}_{\mathbb{B}L}(a_1, a_n), \mathcal{T}_{\mathbb{B}U}(a_1, a_n)], [\mathcal{F}_{\mathbb{B}L}(a_1, a_n), \mathcal{F}_{\mathbb{B}U}(a_1, a_n)]) \\ &+ ([\mathcal{T}_{\mathbb{B}L}(a_2, a_1), \mathcal{T}_{\mathbb{B}U}(a_2, a_1)], [\mathcal{F}_{\mathbb{B}L}(a_2, a_1), \mathcal{F}_{\mathbb{B}U}(a_2, a_1)]) \\ &+ ([\mathcal{T}_{\mathbb{B}L}(a_2, a_3), \mathcal{T}_{\mathbb{B}U}(a_2, a_3)], [\mathcal{F}_{\mathbb{B}L}(a_2, a_3), \mathcal{F}_{\mathbb{B}U}(a_2, a_3)]) + \dots + \\ &([\mathcal{T}_{\mathbb{B}L}(a_2, a_n), \mathcal{T}_{\mathbb{B}U}(a_2, a_n)], [\mathcal{F}_{\mathbb{B}L}(a_2, a_n), \mathcal{F}_{\mathbb{B}U}(a_2, a_n)]) + \dots + \\ &([\mathcal{T}_{\mathbb{B}L}(a_n, a_1), \mathcal{T}_{\mathbb{B}U}(a_n, a_1)], [\mathcal{F}_{\mathbb{B}L}(a_n, a_1), \mathcal{F}_{\mathbb{B}U}(a_n, a_1)]) \\ &+ ([\mathcal{T}_{\mathbb{B}L}(a_n, a_2), \mathcal{T}_{\mathbb{B}U}(a_n, a_2)], [\mathcal{F}_{\mathbb{B}L}(a_n, a_2), \mathcal{F}_{\mathbb{B}U}(a_n, a_2)]) + \dots + \\ &([\mathcal{T}_{\mathbb{B}L}(a_n, a_{n-1}), \mathcal{T}_{\mathbb{B}U}(a_n, a_{n-1})], [\mathcal{F}_{\mathbb{B}L}(a_n, a_{n-1}), \mathcal{F}_{\mathbb{B}U}(a_n, a_{n-1})]) \\ &= 2([\mathcal{T}_{\mathbb{B}L}(a_1, a_2), \mathcal{T}_{\mathbb{B}U}(a_1, a_2)], [\mathcal{F}_{\mathbb{B}L}(a_1, a_2), \mathcal{F}_{\mathbb{B}U}(a_1, a_2)]) \\ &+ 2([\mathcal{T}_{\mathbb{B}L}(a_1, a_3), \mathcal{T}_{\mathbb{B}U}(a_1, a_3)], [\mathcal{F}_{\mathbb{B}L}(a_1, a_3), \mathcal{F}_{\mathbb{B}U}(a_1, a_3)]) \\ &+ 2([\mathcal{T}_{\mathbb{B}L}(a_1, a_n), \mathcal{T}_{\mathbb{B}U}(a_1, a_n)], [\mathcal{F}_{\mathbb{B}L}(a_1, a_n), \mathcal{F}_{\mathbb{B}U}(a_1, a_n)]) \\ &= 2([\sum_{a_i \neq a_j} \mathcal{T}_{\mathbb{B}L}(a_i, a_j), \sum_{a_i \neq a_j} \mathcal{T}_{\mathbb{B}U}(a_i, a_j)], [\sum_{a_i \neq a_j} \mathcal{F}_{\mathbb{B}L}(a_i, a_j), \sum_{a_i \neq a_j} \mathcal{F}_{\mathbb{B}U}(a_i, a_j)]) \end{aligned}$$





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$$=(2[\sum_{a_i \neq a_j} \mathfrak{F}_{\mathbb{B}L}(a_i, a_j), \sum_{a_i \neq a_j} \mathfrak{F}_{\mathbb{B}U}(a_i, a_j)], 2[\sum_{a_i \neq a_j} \mathfrak{F}_{\mathbb{B}L}(a_i, a_j), \sum_{a_i \neq a_j} \mathfrak{F}_{\mathbb{B}U}(a_i, a_j)])$$

Hence the proof.

Example 2.17

Consider Figure 3 from Example 2.14

$$\mathfrak{d}(a_1) = ([0.2, 0.7], [0.8, 1.2])$$

$$\mathfrak{d}(a_2) = ([0.1, 0.4], [0.3, 0.6])$$

$$\mathfrak{d}(a_3) = ([0.1, 0.3], [0.5, 0.6])$$

Here

sum of all vertex degrees of truth membership = [0.4, 1.4]

sum of all vertex degrees of falsity membership = [1.6, 2.4]

sum of all edge degrees of truth membership = [0.2, 0.7]

sum of all edge degrees of falsity membership = [0.8, 1.2]

Based on this, sum of all vertex degrees of truth and falsity membership is twice the sum of all edge degrees of truth and falsity membership.

CONCLUSION

The piece of writing presents a novel concept pertaining to the PIFG and PIVIFG, outlining their respective definitions and providing illustrative examples to enhance understanding.

REFERENCES

1. A.Nagoor Gani & S.Shajitha Begum " Degree, Order and Size in Intuitionistic Fuzzy Graphs", International Journal of Algorithms, Computing and Mathematics Volume 3, Number 3, August 2010
2. Atanassov, K., "Intuitionistic Fuzzy Sets", Fuzzy Sets and Systems, Vol 20, pp.87-96, 1986
3. Krassimir T. Atanassov, Intuitionistic Fuzzy Sets Theory and Applications, 1999, Springer Physica-Verlag Publishing house
4. Mohamed Ismayil and A. Mohamed Ali. On Strong Interval-Valued Intuitionistic Fuzzy Graph, in "International Journal of Fuzzy Mathematics and Systems", Volume 4, Number 2, 2014, pp.161-168.
5. Nagoor Gani and M. Basheer Ahamed. Order and size in fuzzy graphs, in a. "Bulletin of Pure and Applied sciences", Vol 22E, No.1, 2003, pp.145-148.
6. Nagoor Gani A. and S. Shajitha Begum. Degree, Order and Size in Intuitionistic Fuzzy Graphs, in "International Journal of Algorithms, Computing and Mathematics", (3)3, 2010
7. S. Yahya Mohamed and A. Mohamed Ali, Interval-valued Pythagorean Fuzzy Graph, Journal of Computer and Mathematical Sciences, Vol.9(10), 1497-1511 October 2018(28)
8. Yager, R.R., "Pythagorean Fuzzy Subsets", In: Proc Joint IFSAWorld Congress and NAFIPS Annual Meeting, Edmonton, Canada, pp.57-61, 2013.(3)
9. Zadeh, L.A., "Fuzzy Sets", Inform. and Control, Vol 8, pp.338-353, 1965. (1)





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Figure 1. PIFG	Figure 2. PIVIFG
Figure 3. PIVIFG	Figure 4. IVFG





Water Quality Assessment of Rural Area Lake of Village Segvi Ta.: Valsad-Gujarat, India

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ABSTRACT

Water is key component for human existence on the earth. Now a day's water pollution is being an increasing problem for most of the nations in the world. As it directly influences public health, affects ecosystems, food chain, local to national economy and many more, hence continuous observation and assessment is required for maintaining water quality. In some cases, it produces irreversible effects on environment nearby the water body. In this present systematic work, some essential quality parameters of pond's water in Village Segvi Ta. Valsad-Gujarat, India has been evaluated on a seasonal basis for the October 2020 to July 2022 These samples were analyzed for twelve different Physico-chemical and three important bio-chemical parameters were tested using standard techniques for water quality assessments. Total eight times (quarterly) testing was carried out and findings were also compared with WHO and BIS Standards. Some results of the analysis showed that seasonal changes were quite similar for both the years. Most of the parameters were in the permissible limits as per standards.

Keywords: Water Quality; Assessment; Pond Water; COD; BOD;

INTRODUCTION

Among all other natural resources water is essential constituents of the environments for living and nonliving too. Lakes, Ponds and surface water reservoirs are the planet's most important fresh water resources as it gives life to the entire living organism to its surroundings as well provide innumerable ecological and social benefits. But due to incensement in the demand of water for versatile uses in industrialization and urbanization it creates scarcity of



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water around the world. More over in general aspects, rural areas use water for many purposes which depends on lake and pond like fresh water sources for their day-to-day anthropogenic activities. Certain standards in terms of its physical, chemical and biological parameters determine its suitability for intended purposes. Water is considered polluted when these parameters shift from the acceptable range of quality standards [1-2]. However, water for human applicability in domestic as well industrial purposes should be free from impurities, disease causing organisms, poisonous substances and excessive amounts of different minerals and other organic matter. It should also be free from unwanted color, any type of turbidity, bad taste and unpleasant odor too. The objective of this work has to analyze various physico-chemical parameters of the water in the *Segvi Lake* situated in village Segvi Ta. Valsad, Gujarat-INDIA.

MATERIALS AND METHODS**STUDY AREA**

This investigation was carried out to evaluate the status of the water quality of Segvi Lake, Google coordinates: 20.589497, 72.910882 and map (Fig-1). It is situated in Village Segvi of Ta. Valsad, Gujarat-INDIA. Valsad district which is located at the southernmost tip of Gujarat; is located at 20.52°N 72.95°E. It has an average elevation of 18 meters (59 feet) above sea level near Gulf of Khambhat in the Arabian Sea. The water of this pond is used for fisheries, agriculture, and partially domestic activities at three Ghats. The present study was conducted to analyze physico-chemical properties of water in the period of one year from October-2020 to July 2022.

SAMPLING OF WATER

The water samples were collected from five different selected points every time in the morning 7:00 am to 11:00 am. During sample collection from the lake, necessary precautions were taken to collect water samples undisturbed. Sampling was done in fresh plastic bottles which were washed with sample water before taking the sample. After washing the closed bottle was dipped into the water keeping the cap upward and then the cap is opened and water is allowed to fill up the bottle fully. Water samples were taken from 10-15 cm depth from the surface of water and immediately transferred to the laboratories for analyses.

METHODS

The methods (Table-1) adopted for the analysis and determination of different testing parameters were followed according to the procedure given in the APHA, AWWA and WPCF, 2005.[2]

EXPERIMENTALS

All the water samples were analyzed for five Physicochemical parameters in which Color, Odor, Temperature (T), pH, EC and one biochemical test of Dissolved Oxygen(DO) were observed and analyzed at sampling point only, the other six parameters like Total Hardness(TH), Turbidity (TB), Electric conduction (EC), Total Dissolved Solid (TDS), Chloride(CL), Sulphate(SL), Nitrate (N), Alkalinity (AL) and Biochemical parameters viz. Chemical Oxygen Demand(COD), Biological Oxygen Demand(BOD). Temperature (T), pH, EC and one biochemical test of Dissolved Oxygen (DO) were noted for average of all five selected sampling points. For rest of the parameters all the five samples were mixed to get better representative sample and it was analyzed using standard operating procedures of APHA [2] given in the Table-1.

RESULTS AND DISCUSSIONS

Results of the observations and experiments were noted regularly after each quarter Viz. Oct-2020, Jan-2021, Apr-2021, July-2021, Oct-2021, Jan-2022, Apr-2022, July-2022. All the Results are given in the Table-2.



**Bhadreshkumar Rameshbhai Sudani****Color**

Color of water in any water body is very important as it shows the status of purity of water in it. The natural color of pond or lake water is typically a **slight blue tint** because of the penetration and absorption of the Sun light. Due to deflection and scattering of blue and violet like shorter wavelengths is higher than others it seems to be light blue in appearance. Moreover, water color can also be influenced by some other factors like dissolved salts and minerals, suspended particles, sediments, and floating plankton. Commonly high clarity of blue color indicates low concentrations of algae and other substances, greenish color indicates presence of high concentrations of chlorophyll-containing algae and brown color of water body indicates existence of high amounts of dissolved organic salts, matter, often from vegetative material like leaves and agricultural waste, which can impart a tea-like coloration. Here in this study, the color of water in the month of October and January found light greenish and in April it found **greenish brown** and **light brown** again in July it found light green it may be due to presence of phytoplankton in the lake during after monsoon, in summer and before monsoon.

Odor

Ideally odor of water in any pond or lake should be fresh and earthy which indicates a healthy ecosystem in and around. If water body emits a foul smell, it could be due to several reasons such as high algae growth, low oxygen levels, eutrophication, the presence of decaying organic or agricultural or biowaste matter like fish or plant waste [8] Here in this study we found the odor of the water body 'pleasant' four times out of eight events, during both the January months we found slightly unpleasant odor followed by musty smell in both April months it may be due to increasing the concentration of organic matter in the lake or more growth of algae in the lake. If we want to maintain the proper odor of the lake water we need to allow proper aeration, agricultural waste removing, filtration or regular maintenance and cleaning of water body can help to maintain the water quality and prevent unpleasant or musty odor.

Temperature

The ideal temperature for a pond or lake in Gujarat, India, can vary based on the specific purpose and the aquatic life you intend to support and also it can be varying according to the seasons like winter, monsoon, spring, fall or summer etc. in the present study we found the temperature in the range from minimum 21 °C to maximum 29 °C which is in the ideal range for aquatic life (**Fig-2**).

pH

According to WHO and BIS the ideal pH range should be 6.5 to 8.5 for drinking water [9-11]. This value of pH for any water body indicates the level of acidity or alkalinity of a solution, hence it is an important limiting factor for water quality parameter and sustainability of water body for better environmental aspects. Here in this study, we found the pH range from minimum 7.2 (**July-2022**) and maximum 8.4 (**April-2022**). Both the lowest pH records were found in the month of July means in the monsoon season may be due to the dilution of rain water. And both the highest pH recorded during the month of April means in the season of pre monsoon which may be due to evaporations and concentration of impurities in the water body. Results (**Fig-2**) shows that both upper and lower level of pH are in the ideal pH range for such water body [9-11].

Total Hardness

Total hardness of water in any water body is the parameter used to identify the level of metallic impurities like two dissolved minerals calcium (Ca) and magnesium (Mg). Both of these minerals usually found in the form of carbonates, bicarbonates, sulphates, chlorides and sometimes nitrates. Calcium and Magnesium are essential for bone and scale formation [10]. In the current study we found minimum from 170 mg/L to maximum up to 245 mg/L which is in the limit as per [9-10]. However it was found lower in the monsoon season and higher in the summer time.

Turbidity

The turbidity range in pond or lake like water bodies can vary significantly depending on several factors viz. suspended solids, sediment, runoff, and other particulates, with different reasons like soil erosion, waste



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contamination or domestic activities. Generally, turbidity in the potable water according to standard should be 1 NTU to 5 NTU but in pond or lake like water body it may be found some level increased. In this study we found minimum **15-16 NTU to 29-31 NTU** in the month of April and July respectively which indicates that after monsoon the upper water level impurities might have sedimented at bottom of lake so it found lesser turbid during summer than in the monsoon or post monsoon season.

Electric Conductance

As like TDS electrical conductance in lake water is a significant indicator of water quality which is used to estimate the amount of mineralization. It is very good useful for getting aware of the effect of diverse ions on chemical equilibrium, physiological effects on plants or animals, and corrosion rates. It has essential role to understand the density of lake water, which affects stratification, circulation patterns, and the overall hydrodynamics of the lake or pond water which is also used to calculate out environmental conditions of the water body. Present study of the lake showed the EC level from **531 $\mu\text{S/cm}$ to 691 $\mu\text{S/cm}$** . Actually, it is slight above the standard of potable water even in all the months where July month results were slight high than others.

Total Dissolved Solid

If we the lake water quality TDS is essential parameter to describe the inorganic salts and small amounts of organic matter present in a dissolved form in the water body. For any ground water sample, it should be below 500 ppm but some time in lake like water body it is found increased due to presence of inorganic salts that can be found in water include calcium, magnesium, potassium and sodium, which are all cations, and carbonates, nitrates, bicarbonates, chlorides and sulfates, which are all anions. In present study we found the level of TDS is in the almost same range as per the results of EC. The highest is **971 mg/L** and lowest is **725 mg/L**. which is quite higher than standard of BIS and WHO for Potable water. Below the range of waste water.

Chloride

The chloride test result reflects concentration determined in mg/L of a lake water sample over the testing span shows a fluctuating pattern with the highest concentration recorded in **April 2022 at 60.5 mg/L** and the lowest in **July 2021 at 44.7 mg/L**. This fluctuation in chloride levels could be indicative of seasonal changes, environmental factors, or human activities influencing the lake's ecosystem.

Sulphate

The sulphate levels exhibit fluctuations, with the highest concentration observed in **April 2022 (60.5 mg/L)** and the lowest in **July 2021 (44.7 mg/L)**. These variations could be attributed to natural seasonal changes, agricultural runoff, or some domestic civil work contaminations nearby. indicates a general upward trend in sulphate concentration within the lake water samples over the period studied, with notable peaks and troughs. For pond water sanitation, consistent monitoring of sulphate levels is very crucial as elevated concentrations can affect aquatic life and water quality in the lake. It is also important to identify the sources of sulphate and manage them effectively to maintain the ecological balance and ensure the water remains safe for its intended uses.

Nitrate

For water quality management, especially concerning lake or pond water sanitation, it is important to monitor nitrate levels as they can impact aquatic life and the overall health of the lake ecosystem. Regular testing and analysis can help maintain these levels within safe limits and identify any potential sources of contamination that may require attention. The results shows that the nitrate levels in the water samples have varied over time, with no clear increasing or decreasing trend with the highest level recorded in October 2020 at **3.5 ppm** and the lowest in April 2022 at **1.1 ppm** which is within the standard limit for potable water even.

Alkalinity

Maintaining alkalinity within appropriate levels is crucial for water sustainability as it affects the buffering capacity of the water and the health of aquatic organisms. Regular monitoring and management of water quality parameters



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are essential to ensure the ecological balance and sustainability of the lake or pond ecosystem. In the present study results shows variability, with a general trend of increasing alkalinity peaking in April 2022 at **110.7 mg/L**. The lowest recorded level is in July 2022 at **77.1 mg/L**. The Segvi lake water experienced periods of higher alkalinity, particularly in the months of January and April of 2021 and 2022, which could be due to seasonal biological activity or external environmental inputs.

Dissolved Oxygen

It is a critical factor in the health of aquatic environments for any lake or pond which gives clear idea about the level of free, non-compound oxygen present in water. The DO level is temperature sensitive and also affected by eutrophication in the water body. Results of DO levels in Segvi lake water during study period shows variability. The highest DO level is recorded in July 2022 at **7.6 ppm**, and the lowest in April 2022 at **4.3 ppm**. The data shows a general decreasing trend from October 2020 to April 2022, followed by an increase in July 2022. The fluctuations could be influenced by seasonal changes, biological activity, or anthropogenic factors. However, the dip in April 2022 to 4.3 ppm could have stressed aquatic organisms. The increase in DO levels in July 2022 is a positive sign, possibly indicating better water aeration or reduced pollution. These DO levels in the water samples fluctuate but generally stay within a range that is considered healthy for most aquatic life. The periodic highs could be due to increased photosynthetic activity or lower water temperatures, while the lows might be influenced by factors such as higher water temperatures or increased organic matter.

Chemical Oxygen Demand

The significance of COD in the sustainability of lake water or ponds is quite profound. It is a measure of the amount of oxygen required to oxidize both organic and inorganic substances in water body. It works as an essential tool for assessing the pollution load and organic content, which directly impacts water quality and aquatic ecosystems. Present study results showed fluctuations over the observed periods. The highest recorded COD was in April 2022 at **613 ppm**, indicating a high level of organic pollutants at that time. The lowest was in July 2022 at **317 ppm**, which suggests a significant improvement in water quality or possibly seasonal variations affecting the measurements. The data from October 2020 to January 2022 shows an overall increasing trend, followed by a sharp decrease in July 2021, then rising again until April 2022, and finally dropping significantly in July 2022. It could be due to increased human activity or runoff during the dry season. The significant reduction in COD by July 2022 could be attributed to the onset of the monsoon, diluting the concentration of pollutants or lesser domestic activities in the water body during the time period.

Biological Oxygen Demand

BOD is an important parameter for assessing water quality in lake or pond like aquatic water systems which gives idea about the amount of DO require by aerobic microorganisms to break down organic material present in lake water as it affects the growth of algae and other aquatic plants. High BOD levels indicate a large presence of biodegradable material, which can signify pollution. The BOD levels in the lake water show a general increasing trend from October 2020 to April 2022, with a peak value of **5.0 ppm** in April 2022. This suggests an increase in biodegradable organic matter during this period. However, there is a noticeable decrease in July of both 2021 and 2022, with values of **2.0 ppm** and **3.0 ppm** respectively, which could be due to seasonal variations such as monsoon dilution or other ecological factors. The fluctuating BOD levels indicate varying degrees of organic pollution over time. High BOD levels can lead to oxygen depletion in the water, adversely affecting aquatic life. The data suggests that there may be periods of increased pollution followed by recovery or dilution phases. Continuous monitoring and management efforts are essential to ensure the sustainability of the lake's ecosystem and to prevent long-term adverse effects on the water quality.



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CONCLUSIONS

The data collected from October 2020 to July 2022 shows fluctuations in various water quality parameters of the lake. The color of the water varied seasonally, with a tendency to be lighter in October and July and darker with a greenish or brown hue in April. The odor followed a similar pattern, being more pleasant in the cooler months and musty during the warmer months. The observed seasonal variations in color and odor are likely influenced by biological activity, such as algae growth, which is more pronounced during warmer months. The increase in temperature during April of each year correlates with higher pH, TH, EC, TDS, and nutrient levels, suggesting that warmer temperatures may accelerate chemical reactions and biological processes in the lake. Overall, the data indicates that the lake's water quality is subject to seasonal changes and possibly anthropogenic influences, which should be further investigated to ensure the health of the aquatic ecosystem and its suitability for various uses.

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REFERENCES

1. N. K. Mehta, A. Kumari., Study of water quality using of physico-chemical parameters of two perennial fish ponds of Darbhanga. *Int. J. Fish Aquat. Stud.* 2022;10(3):128-132. DOI: <https://doi.org/10.22271/fish.2022.v10.i3b.2683>
2. APHA. Standard Methods for the Examination of Water and Wastewater. 20th ed., Analysis of Water and Wastewater, American Public Health Association, Washington DC, USA, 2005.
3. M. Chakroborty, et. AL., Studies on Physico Chemical Parameters of 5 water bodies of Ranchi (Jharkhand), *Balneo Res. J.*, 2017;8(1) 51-57. DOI: <http://dx.doi.org/10.12680/balneo.2017.142>
4. D. V. Vara Prasad, L. Y. Venkataramana, V. Balasubramanian and K. Divya, Multivariate Time Series Forecasting for Water Quality Prediction using ML and DL Models, *Ind. Jour. of Nat. Sci.*, 2024;14(82): 69784-69794.
5. V. Srinivasan, U. Natesan and A. Parthasarathy, Seasonal Variability of coastal water quality in Bay of Bengal and Palk Strait, Tamilnadu, Southeast coast of India'. *Int. J. Braz. Arch. Biol. Technol.*, 2013;56(5): 875-884.
6. Sneha M, Sahu K K. Physico-Chemical Analysis of Ponds and River Water in Darbhanga. *Int. J. of Creative Re. Thoughts.* 2020;8(12):1428-1444.
7. Ministry of Works and Housing Drinking Water Standards 1975. In "Chemical and biological methods for water pollution studies" by Trivedi, R.K. and Goel, P.K, Environmental Publications, Karad, Maharashtra, India, 1984.
8. Akhtar, N.; Syakir Ishak, M.I.; Bhawani, S.A.; Umar, K. Various Natural and Anthropogenic Factors Responsible for Water Quality Degradation: A Review. *Water* 2021, 13, 2660. <https://doi.org/10.3390/w13192660>.
9. World Health Organization (WHO) Guideline for Drinking Water Quality. Geneva. 2009.
10. ICMR. Manual of Standards of Quality of Drinking Water Supplies, Indian Council of Medical Research, New Delhi. 1975.
11. Ancy Mol P and Shaji E. Physico-Chemical Characteristics of Surface Water Quality of Urban Ponds in Thiruvananthapuram District, Kerala. *IJETST.* 2016; 3(1):3431-3437.
12. R. Bhatelia and D. Jain, Water quality assessment of lake water: a review, *Sustain. Water Resour. Manag.* (2016) 2:161–173. <https://doi.org/10.1007/s40899-015-0014-7>





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Table-1. Methods of analysis

Physicochemical parameters		
Sr. No.	Study parameter	Method
1	Color	Direct Observation
2	Odor	Direct Observation
3	Temperature (T)	Digital Thermometer
4	pH	Digital pH Meter
5	Total Hardness (TH)	Complexometric titration by EDTA
6	Turbidity (TB)	Nephelometric method
7	Electric conduction (EC)	Digital conductivity meter
8	Total Dissolved Solid (TDS)	TDS meter
9	Chloride (CL)	Argentometric titration
10	Sulphate (SL)	Titrimetric method with Ba ²⁺
11	Nitrate (N)	Spectroscopic method
12	Alkalinity (AL)	Titrimetric method
Biochemical Parameters		
Sr. No.	Study parameter	Method
1	Dissolved Oxygen (DO)	Standard Winkler Method
2	Chemical Oxygen Demand (COD)	Open condensation - digestion by titration
3	Biological Oxygen Demand (BOD)	Standard 5 days BOD Test

Table 2: Results of all experimental analysis

Sample Test	October 2020	January 2021	April 2021	July 2021	October 2021	January 2022	April 2022	July 2022
Color	Light green	Light green	Greenish brown	Light green	Light green	Light green	Light brown	Light green
Odor	Pleasant	Slight Unpleasant	Musty	Pleasant	Pleasant	Slight Unpleasant	Musty	Pleasant
Temp °C	23.0	21.0	28.0	24.0	22.0	20.0	29.0	25.0
pH	7.4	7.9	8.3	7.3	7.5	8.0	8.4	7.2
TH mg/L	180	195	214	170	185	202	245	180
TB NTU	29	20	15	28	28	19	16	31
EC µS/cm	581	546	531	654	571	559	595	691
TDS mg/L	820	763	725	918	805	780	826	971
CL mg/L	46.8	49.8	55.6	44.7	47.7	51.1	60.5	47.2
SL mg/L	26.0	35.0	46.0	24.0	26.0	38.0	49.0	22
N ppm	3.5	2.1	1.2	3.1	2.9	1.9	1.1	2.8
AL mg/L	82.0	98.4	109.3	81.5	84.4	101.8	110.7	77.1
DO ppm	7.3	6.5	5.2	7.5	6.9	6.4	4.3	7.6
COD ppm	415	504	561	329	466	516	613	317
BOD ppm	2.5	3.5	4.5	2.0	3.0	4.0	5.0	3.0





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Figure 1: Google Map of Study Area Segvi Lake (Valsad-GUJARAT-INDIA)

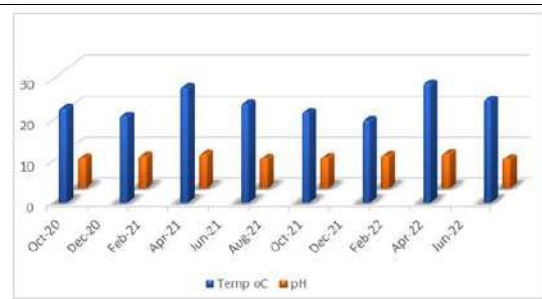


Figure 2: Temperature in OC and pH of the Lake water

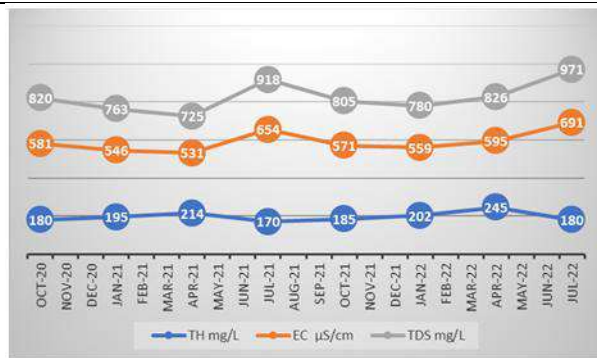


Figure 1: TH, EC and TDS comparison

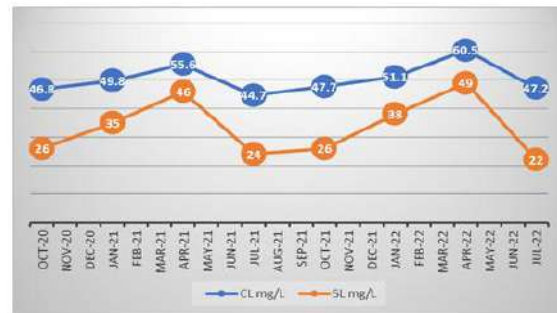


Figure 2: CL and SL comparison

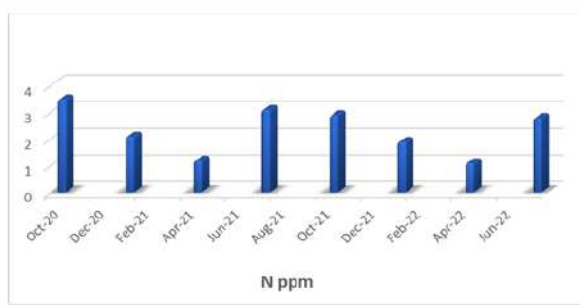


Figure 5: Nitrate (N) in ppm

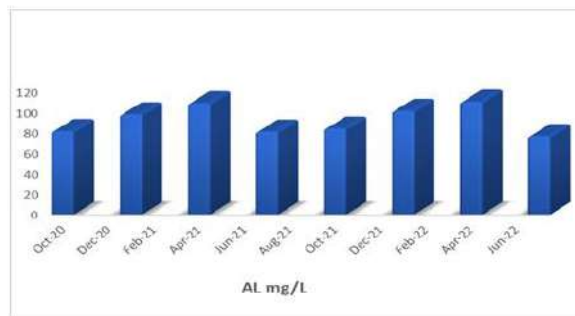


Figure 3: Alkalinity in mg/L

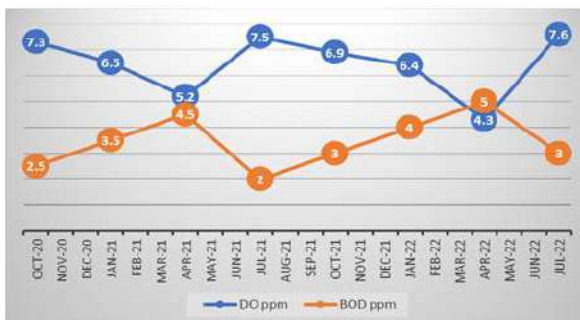


Figure 7: DO and BOD comparison

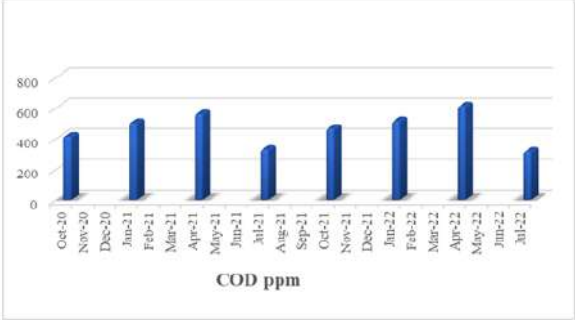


Figure 8: COD in ppm





The Role of Neuromarketing in Persuasive Consumer Choices of Wearable Fitness Devices in Bengaluru

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ABSTRACT

Neuromarketing is the study of how marketing stimuli affect the human brain. Consumers make subconscious decisions based on the idea that commercial stimuli can affect their brains unconsciously. Wearable fitness devices are becoming increasingly popular in Bangalore, as consumers become more health conscious and look for ways to track their activity levels and fitness goals. Neuromarketing can be used for marketing campaigns more effective types for wearable fitness equipment by understanding how consumer brains respond to marketing messages. Neuromarketing can be used to sell wearable exercise devices by targeting the mirror neuron system and the reward system. Social influence plays a significant role in shaping consumer choices of wearable fitness devices. Consumers are more likely to buy a wearable fitness device if they see it being used by their friends or family, or if it is endorsed by a celebrity they admire. This study will explore the role of neuromarketing in shaping consumer choices of wearable fitness devices in Bengaluru. It will identify the key neuromarketing factors that can be used to market wearable fitness devices more effectively, and it will provide recommendations for marketers on how to use these factors to reach their target audiences using structured questionnaire method.

Keywords: Neuro Marketing, Wearable Fitness Devices, Social Influence, Strategy and Consumer.





INTRODUCTION

The people of Bengaluru, India are becoming more health-conscious and are increasingly using wearable fitness devices to track their activity levels, fitness goals, and overall health. However, the market for wearable fitness devices is highly competitive, so marketers need to find innovative ways to differentiate themselves. Neuromarketing, a field of marketing that studies how the human brain responds to marketing stimuli, can provide insights into consumer decision-making and help marketers develop more effective marketing campaigns for wearable fitness devices. According to a report by Strategy Analytics, the global shipments of wearable fitness devices are predicted to reach 274 million units by 2026. Neuromarketing is a useful tool for understanding consumer behavior and preferences. It involves observing and analyzing brain activity in response to marketing stimuli using techniques such as neuroimaging and electroencephalography (EEG). This information can then be used to develop more effective marketing strategies that resonate with consumers' subconscious motivations and decision-making processes. In the context of wearable fitness devices, neuromarketing can provide insights into the factors that influence consumer choices, such as

- Emotional Appeal: Understanding how consumers react emotionally to different marketing messages can help marketers create more persuasive campaigns that evoke positive associations with their products.
- Sensory Engagement: Wearable fitness devices are often associated with health and well-being. Neuromarketing can help marketers tap into these sensory experiences by creating campaigns that evoke feelings of comfort, vitality, and achievement.
- Social Influence: Social proof and peer recognition are powerful motivators. Neuromarketing can help marketers leverage social influence by showcasing how others are using and benefiting from wearable fitness devices.

Neuromarketing Perspective on Social Influence

Neuromarketing is a field of marketing that studies how the human brain responds to marketing stimuli. By understanding how the brain processes social influence, marketers can develop more effective marketing campaigns. One way that social influence can influence the brain is through the activation of the mirror neuron system. The mirror neuron system is a network of neurons in the brain that is activated when we observe the actions of others. When we see someone using a wearable fitness device, our mirror neuron system is activated, which makes us feel like we are using the device ourselves. This can lead to a more positive attitude towards the device and an increased likelihood of purchasing it. Social influence can impact the brain in various ways, one of them being the release of dopamine. Dopamine is a neurotransmitter that is associated with pleasure and reward. For instance, when we see someone using a wearable fitness device and enjoying it, it can trigger the release of dopamine in our own brains, which can make us feel motivated to purchase the device ourselves. Furthermore, social media has a significant impact on social influence. Nowadays, people often use social media to share their fitness goals and progress with their friends and followers. This creates a sense of community and support, which motivates consumers to purchase and use wearable fitness devices.

Implications for Marketers of Wearable Fitness Devices:

The findings of neuromarketing research on social influence have important implications for marketers of wearable fitness devices. Firstly, marketers should concentrate on developing marketing campaigns that take advantage of social influence. For instance, they can collaborate with celebrities or influencers to endorse their products. They can also encourage consumers to share their fitness goals and progress on social media. Secondly, marketers should design wearable fitness devices that are user-friendly and easy to share with others. Some wearable fitness devices enable users to effortlessly share their data with their friends and followers on social media. Thirdly, marketers should focus on creating a strong community around their brand of wearable fitness device. This can be achieved by establishing online forums and social media groups where users can interact with each other and share their experiences.



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REVIEW OF LITERATURE

Neuromarketing is the practice of using neuroscience in marketing. It involves measuring an individual's response to specific products, packaging, advertising, or other marketing elements through brain imaging, scanning, or other brain activity measurement technologies (Devaru, 2018). The study showed that the presence of celebrities or people considered physically beautiful in advertisements activates an area of the brain involved in the process of recognizing and building trust (Fortunato et al., 2014). The Advances in neuroscience teach how the human brain works, deep inside the skull to examine how advertising and marketing messages affect the brain. Also, it exposes many of the little things that happen in the minds, usually, unconsciously, that may make or break the success of any marketing campaign (Parchure, Parchure, & Bora, 2020). Areas of neuromarketing search applications have many and varied applications, such as creating products in which taste, structure or aroma are vital, architecture and plan for new constructions, movie trailers, advertising utility, website design — all of these can be the result of a pervasive realm of emotion, interest, belief, loyalty, or fear (Joy, 2018). Neuromarketing is an interdisciplinary field that aims to understand consumer behavior by studying the brain through the use of various techniques, such as neuroimaging. The research aims to measure the impact on an individual market stimulus and thus provide new ways to understand how the consumer stores, incorporates, processes, and uses the wide range of information received on a daily basis (Jordão et al., 2017). Neuromarketing is a relatively new field of science, which applies neuroscientific research methods such as eye-tracking and functional magnetic resonance imaging of the brain in real- lifesettings to assess stimuli, in order to find out how consumers make decisions based on the marketing stimuli that is targeted at them. Lee et al. (2007) described the term neuromarketing as “the application of neuroscientific methods in analysing and understanding how humans behave in reference markets and the marketing exchanges”. SMM remains to be considered as a new marketing strategy, but how it impacts intentions is limited. But, to date, a lot of research on SMM is focused on consumer’s behavior, creative strategies, content analysis and the benefits of user-generated content, and their relevance to creating virtual brand communities (Ibrahim, 2021).

MATERIAL AND METHODS

Statement of the problem

The usage of wearable fitness devices has significantly increased in recent years, and this trend can be attributed to various factors, such as emotional appeal, sensory engagement, and social influence. Neuromarketing plays a crucial role in influencing and inducing customers to adopt these devices by leveraging these factors. The purpose of this study is to examine the impact of neuromarketing strategies' social influence on customers' behavior towards wearable fitness devices.

RESEARCH DESIGN

Objective

1. To analyze the role of social influence of neuromarketing across the gender of the study.
2. To investigate the buying behavior of the consumers across the genders of the study.

Data Collection

Source: Primary

No. of respondents targeted: 150

No. of the responses received: 104.

Limitation of the study

Time is restricted to the period of the study between October-December 2023. Analyses and findings based on the study conducted.



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RESULTS AND DISCUSSION

It represents the items included to test the social influence of neuro marketing strategies are set to the standard required as it is satisfying the rule of thumb. The application of non-parametric analysis of Mann Whitney U test:

H₀: there is no significant relationship between social influence of neuro marketing strategies and gender.

H_a: there is a significant relationship between social influence of neuro marketing strategies and gender.

Interpretation

Since the p value is 0.004, null hypothesis is rejected and it is shown that there is no relationship between social influence of neuro marketing strategies and gender. To understand the further details on which gender get inclined by the social influence of neuro marketing strategies legacy dialog of Mann-whitney U test was run and the result shows as below:

Interpretation

Since the p value is 0.004, null hypothesis is rejected and it is shown that there is no relationship between social influence of neuro marketing strategies and gender. To understand the further details on which gender get inclined by the social influence of neuro marketing strategies legacy dialog of Mann-whitney U test was run and the result shows as below:

Inference

The table clearly shows that female gender plays significant role in getting inclined by the social influence of neuro marketing strategies towards the purchase of wearable fitness devices than male.

Objective

2 To investigate the buying behavior of the consumers of the across the gender of the study. Represents the application of non-parametric analysis of Mann Whitney U test:

H₀: there is no significant relationship between the buying behavior of consumer of wearable fitness devices and the gender of the study.

H_a: there is a significant relationship between the buying behavior of consumer of wearable fitness devices and the gender of the study.

Interpretation: Since the p value is 0.058, null hypothesis is accepted and it is shown that there is a relationship between buying behavior of consumer of wearable fitness devices and the gender of the study. To understand the further details on which gender get inclined by the buying behavior of wearable fitness devices, legacy dialog of Mann-whitney U test was run and the result shows as below:

Inference: The table clearly shows that female gender plays significant role in getting inclined by the buying behavior of wearable fitness devices than male.

CONCLUSION AND FINDINGS

The findings from the study strongly suggest that women exhibit a heightened interest in acquiring wearable fitness devices compared to men. This inclination appears to be notably influenced by the persuasive impact of neuro-marketing strategies employed within social contexts. Additionally, the purchasing patterns observed among females demonstrate a greater engagement and propensity towards acquiring these devices in comparison to their male counterparts.





REFERENCES

1. Fortunato, V., Giraldo, J. d. M. E., & de Oliveira, J. (2014). A review of studies on neuromarketing: Practical results, techniques, contributions and limitations. *Journal of Management Research*, 6(2), 201–220. <https://doi.org/10.5296/jmr.v6i2.5446>
2. Jordão, I. L. D. S., De Souza, M. T., de Oliveira, J. H. C., & Giraldo, J. d. M. E. (2017). Neuromarketing applied to consumer behaviour: An integrative literature review between 2010 and 2015. *International Journal of Business Forecasting and Marketing Intelligence*, 3(3), 270–288. <https://doi.org/10.1504/IJBFMI.2017.085371>
3. Ibrahim, B., and Aljarah, A. (2018). Dataset of relationships among social media marketing activities, brand loyalty, revisit intention Evidence from the hospitality industry in Northern Cyprus. *Data Brief* 21, 1823–1828. doi: 10.1016/j.dib.2018.11.024
4. Joy, M. M. (2018). The potential and challenge of using neuromarketing as a marketing tool. In Proceedings of National Conference New-Age Marketing NCNAM-2018. Retrieved from <https://www.researchgate.net/publication/324029219>
5. Lee, N., Broderick, A. J., & Chamberlain, L. (2007). What is "neuromarketing"? A discussion and agenda for future research. *International Journal of Psychophysiology*, 63(2), 199–204.
6. Parchure, N. P., Parchure, S. N., & Bora, B. (2020). Role of neuromarketing in enhancing consumer behavior. In American Institute of Physics Conference Series, 2273(1), 060005. <https://doi.org/10.1063/5.0024517>

Table . 1 AGE GROUP

AGE GROUP	PERCENT
Upto 20 years	7.7
21-30 years	30.8
31-40 years	46.2
41-50 years	15.4
Total	100.0

Table. 2 GENDER

GENDER	PERCENT
Female	46.2
Male	53.8
Total	100.0

Table .3 EDUCATION LEVEL

Education	Percent
SSLC	23.1
PUC	23.1
Under graduation	46.2
Post Graduation	7.7
Total	100

Table 4 OCCUPATION

Occupation	Percent
Student	15.4
Working(Private/Public)	61.5
Entrepreneur	15.4
HUsewife	7.7





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Total	100.0
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Table 5 AWARENESS LEVEL

LEVEL USAGE OF WEABLE DEVICES	
Status	Percent
Yes	84.6
No	15.4
Total	100.0

Table: 6 Type of Weable Fitness Device Usage

TYPE OF WEABLE FITNESS DEVICES USGAE	
TYPES	Percent
Accessory Based wearable devices	92.3
Textile based wearable devies	7.7
Total	100.0

Table 7 : Normality of the items considered for the study of social influence of neuro marketing strategies.

Tests of Normality						
	Kolmogorov-Smirnov ^a			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
SFNM	.271	80	.000	.801	80	.000

a. Lilliefors Significance Correction

The table reflects the data is not normal since the p value of Shapiro-wilk is 0.000.

Table 8 : Objective: 1 To analyze the role of social influence of neuro marketing across the gender of the study.

Reliability Statistics	
Cronbach's Alpha	N of Items
.973	7

The table reflects the reliability analysis result which is 0.973.

Table 9

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of SFNM is the same across categories of Gender.	Independent-Samples Mann-Whitney U Test	.004	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Table 10

Ranks				
Gender		N	Mean Rank	Sum of Ranks
SFNM	Female	32	49.50	1584.00
	Male	48	34.50	1656.00
Total		80		





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Table 11: Normality of the items considered for the study of buying behavior of consumers towards the purchase of wearable fitness devices

Tests of Normality						
BBNM	Kolmogorov-Smirnov ^a			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
	.278	104	.000	.864	104	.000

a. Lilliefors Significance Correction

The table reflects the data is not normal since the p value of Shapiro-wilk is 0.000.

Table 10

Hypothesis Test Summary				
	Null Hypothesis	Test	Sig.	Decision
1	The distribution of BBNM is the same across categories of Gender.	Independent-Samples Mann-Whitney U Test	.058	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Table :11

Ranks				
BBNM	Gender	N	Mean Rank	Sum of Ranks
	Female	48	58.50	2808.00
	Male	56	47.36	2652.00
	Total	104		





A Novel Method for Solving Uncertain Differential Equations

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ABSTRACT

In this paper, a study of the numerical method for solving the first order fuzzy initial value problems (FIVP) based on Seikkala derivative of fuzzy process is done. The fourth order Runge-Kutta method based on linear combination of Arithmetic mean, Geometric mean and Root mean square is used to find the numerical solution of the first order FIVP's. This approach is demonstrated through the resolution of a first-order FIVP with triangular fuzzy number and trapezoidal fuzzy number. The results show that the proposed method suits well to find the numerical solution of first – order FIVPs.

Keywords: First order Fuzzy Initial Value Problems, Runge-Kutta method, Arithmetic Mean, Geometric Mean and Root Mean Square, triangular fuzzy number, trapezoidal fuzzy number.

INTRODUCTION

Since the time of Newton, one of the main problems of mathematicians is the resolution of various differential equations. Practically, the immense quantity of these equations were not resolvable in the analytical aspect. This has led to the development of numerical methods for their resolution. The method of Runge-Kutta, named RK is used to find a good numerical result. In recent years Fuzzy Differential Equations leads a natural way to model dynamical systems under uncertainty. This Fuzzy Differential Equations (FDEs) find applications in a wide range of subjects but precisely more in many branches of engineering and medicine. First order linear fuzzy differential equations are one of the simplest fuzzy differential equation, which appears in many applications. Chang S.L. and Zadeh L.A. in [7] first introduced the concept of fuzzy derivative. It was followed up by Dubois.D and Prade[10]. who used extension





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principle in their approach. The term “fuzzy differential Equation” was introduced in 1987 by Kandel.A and Byatt.W.J[15]. They have given many suggestions for the definition of fuzzy derivative to study “fuzzy differential Equation”. In the literature, there are several approaches to study fuzzy differential equations. The first and most popular one is Hukuhara derivative made by Puri.M.L Ralesu.D.A [18]. Seikkala [19] rigorously treated the FDE and the initial value problem (Cauchy problem). Here the solution of fuzzy differential equation becomes fuzzier as time goes on. This approach does not reproduce the rich and varied behaviour of ordinary differential equations. Bede.B and Gal.S.G [7,8] have introduced another concept of derivatives called the generalized Hukuhara derivative. Under this interpretation, the solution of a fuzzy differential equation becomes less fuzzier as time goes on. A strong generalized derivative is defined for a large class of fuzzy number valued function than the Hukuhara derivative. Recently many research papers are focused on numerical solution of fuzzy initial value problems (FIVPS). Numerical Solution of fuzzy differential equations has been introduced by M.Ma, M.Friedman, and Kandel.A in [17] through Euler method. S.Abbasbandy and T.Allahviranloo [1] solved using through Taylor’s method. Runge –Kutta methods have also been studied by authors [2,21]. The existence of solutions for fuzzy differential equations have been extensively studied by several other authors in [3,4]. It is difficult to obtain an exact solution for fuzzy differential equations and hence several numerical methods were proposed in [11,12,13,14]. V.Nirmala, N.Saveetha, S.Chenthurpandiyan discussed numerical Solution of fuzzy differential equation by Runge-Kutta method with higher order derivative approximations [20]. R.Gethsi sharmila & E.C.Henry Amirtharaj investigate numerical solutions of first order fuzzy initial value problems by non-linear Trapezoidal formulae based on variety of Means[13]. Fourth order Runge-kutta embedded heronian mean was studied by R.Ponalagusamy and S.Senthilkumar [22]. A new numerical technique to work out the linear first-order fuzzy differential equations is presented in this paper. We have used the fourth-order Runge-Kutta method based on a linear combination of AM (Arithmetic Mean), GM (Geometric Mean) and RTMS (Root Mean Square). The paper is organized as follows. In Section 2, some basic fuzzy number concepts and fuzzy derivatives are given. In Section 3, the fuzzy initial value problem is dealt with using the extension principle of Zadeh and the concept of fuzzy derivative. In Section 4, a fourth order Runge-kutta method based on a linear combination of AM (Arithmetic Mean), GM (Geometric Mean) and RTMS (Root Mean Square) is introduced. In Section 5, the proposed method is checked by solving two example problems. Section 6 comprises the conclusion.

PRELIMINARIES

Definition 2.1 (fuzzy set):

“A fuzzy set is represented as $\bar{A} = \{(u, \mu_{\bar{A}}(u) : u \in X, \mu_{\bar{A}}(u) \in [0, 1])\}$ In the pair $\{u, \mu_{\bar{A}}(u)\}$, the first variable u corresponds to the classical set, and the second variable $\mu_{\bar{A}}(u)$ is associated with the membership function, which takes values in the interval $[0, 1]$ ”.

Definition 2.2 (α -cut of a fuzzy set)

“The α -level set (or confidence level at α or α -cut) of the fuzzy set of X is a crisp set α that includes all the elements of X whose membership values are $\geq \alpha$; that is, $\bar{A}_\alpha = \{w, \mu_{\bar{A}}(w) \geq \alpha, w \in X, 0 < \alpha \leq 1\}$ ”

Definition 2.3 (fuzzy number)

“The fuzzy number is defined as follows: if R is the set of all real numbers and RF is the set of all fuzzy numbers on R , then a mapping such that $x : R \rightarrow [0, 1]$ is a fuzzy number and it satisfies the following four properties:

- (i) x is upper semi-continuous.
- (ii) x is fuzzy convex; that is, $(\lambda a + (1 - \lambda)b) \geq \min\{x(a), x(b)\}$ for all $a, b \in R, \lambda \in [0, 1]$.
- (iii) x is normal; that is, $\exists a_0 \in R$ for which $(a_0) = 1$.
- (iv) $\text{supp } x = \{a \in R \mid (a) > 0\}$ is the support of x , and the closure of $(\text{supp } x)$ is compact.





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Equally, the parametric definition is also given as follows: A fuzzy number x , which is in parametric form, is a pair that satisfies the following properties:

1. It is a bounded, left-continuous, monotonically increasing function over $[0, 1]$.
2. It is a bounded, left-continuous, monotonically decreasing function over $[0, 1]$.
3. A crisp number α is simply represented by $\underline{u}(r) \leq \bar{u}(r)$, $0 \leq r \leq 1$. and $A_\alpha = [(a_1 - a_2)\alpha + \alpha_1, -(a_4 - a_3)\alpha + a_4]$

Definition: 2.4 (Triangular Fuzzy Number)

The definition of a triangular fuzzy number is characterized by three parameters: $\{\alpha, \beta, \gamma\}$, where the graph of $u(x)$, the membership function of the fuzzy number u , forms a triangular shape with its base spanning the interval $[\alpha, \gamma]$ and its apex located at $x = \beta$. We represent u as $\{\alpha, \beta, \gamma\}$. The membership function for the triangular fuzzy number $\{\alpha, \beta, \gamma\}$ is defined as follows:

$$u(x) = \begin{cases} \frac{x - \alpha}{\beta - \alpha}, & \alpha \leq x \leq \beta \\ \frac{x - \gamma}{\beta - \gamma}, & \beta \leq x \leq \gamma \end{cases}$$

- (1) $u(x) = 0$ if $x < \alpha$
- (2) $u(x) = (x - \alpha) / (\beta - \alpha)$ if $\alpha \leq x < \beta$
- (3) $u(x) = (\gamma - x) / (\gamma - \beta)$ if $\beta \leq x \leq \gamma$
- (4) $u(x) = 0$ if $x > \gamma$

Definition 2.5(Trapezoidal Fuzzy Number):

“A Trapezoidal Fuzzy Number is denoted as $A = (c_1, c_2, c_3, c_4)$ and is defined by the membership function

$$\mu_A(x) = \begin{cases} 0, & x < c_1 \\ \frac{x - c_1}{c_2 - c_1}, & c_1 \leq x \leq c_2 \\ 1, & c_2 \leq x \leq c_3 \\ \frac{c_4 - x}{c_4 - c_3}, & c_3 \leq x \leq c_4 \\ 0, & x > c_4 \end{cases}$$

α -cut interval of this shape is written below.

$$\forall \alpha \in [0,1], \quad A_\alpha = [(c_1 - c_2) + c_1, -(c_4 - c_3)\alpha + c_4]$$

When $c_2 = c_3$ the trapezoidal fuzzy number coincides with triangular one.”

Seikkala derivative

“ The Seikkala derivative $y'(t)$ of a fuzzy process is defined by $[y'(t) \oplus y'(t; \oplus), y'(t; \oplus) \oplus y'(t; \oplus)] \in \mathbb{I}, \quad 0 \leq t \leq 1$ provided that this equation defines a fuzzy number, as in [24]”





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Lemma

“If the sequence of non-negative number $\{W_n\}_{n=0}^m$ satisfy $|W_{n+1}| \leq A|W_n| + B, 0 \leq n \leq N-1$ for the given positive constants A and B, then $|W_n| \leq A^n |W_0| + B \frac{A^n - 1}{A - 1}, 0 \leq n \leq N$.”

Lemma

“If the sequence of non-negative numbers $\{W_n\}_{n=0}^m, \{V_n\}_{n=0}^N$ satisfy $|W_{n+1}| \leq |W_n| + A \max\{|W_n|, |V_n|\} + B, |V_{n+1}| \leq |V_n| + A \max\{|W_n|, |V_n|\} + B$ for the given positive constants A and B ,then $U_n = |W_n| + |V_n|, 0 \leq n \leq N$ we have, $U_n \leq \bar{A}^n U_0 + B \frac{\bar{A}^n - 1}{\bar{A} - 1}, 0 \leq n \leq N$ where $\bar{A} = 1 + 2A$ and $\bar{B} = 2B$.”.

Lemma

“Let $F(t, u, v)$ and $G(t, u, v)$ belong to $C^1(R_F)$ and the partial derivatives of F and G be bounded over R_F . Then for arbitrarily fixed $r, 0 \leq r \leq 1$ $D(y(t_{n+1}), y^0(t_{n+1})) \leq h^2 L(1 + 2C)$ where L is a bound of partial derivatives of F and G and $C = \text{Max}\left\{G\left[t_N, \underline{y}(t_N; r), \bar{y}(t_{N-1}; r)\right], r \in [0, 1]\right\} < \infty$ ”

Theorem

Let $F(t, u, v)$ and $G(t, u, v)$ belong to $C^1(R_F)$ and the partial derivatives of F and G be bounded over R_F . Then for arbitrarily fixed $r, 0 \leq r \leq 1$,then the numerical solutions of $\underline{y}(t_{n+1}; r)$ and $\bar{y}(t_{n+1}; r)$ converge to the exact solutions $\underline{Y}(t_{n+1}; r)$ and $\bar{Y}(t_{n+1}; r)$ uniformly in t.

Theorem

Let $F(t, u, v)$ and $G(t, u, v)$ belong to $C^1(R_F)$ and the partial derivatives of F and G be bounded over R_F and $2Lh < 1$. Then for arbitrarily fixed $0 \leq r \leq 1$, the iterative numerical solutions of $\underline{y}^{(j)}(t_n; r)$ and $\bar{y}^{(j)}(t_n; r)$ converge to the numerical solutions $\underline{y}(t_n; r)$ and $\bar{y}(t_n; r)$ in $t_0 \leq t_n \leq t_N$, when $j \rightarrow \infty$.

FUZZY CAUCHY PROBLEM

Consider the Fuzzy Initial Value Problem

$$\begin{cases} y'(t) = f(t, y(t)), t \in I = [0, T], \\ y(0) = y_0, \end{cases}$$

Where f is a continuous mapping from $R_+ \times R$ into R and $y_0 \in E$ with r-level sets

$$[y_0]_r = [y_1(0; r), y_2(0; r)], r \in (0, 1]$$

The extension principles of Zadeh leads to the following definition of $f(t, y)$ when $y = y(t)$ is a fuzzy number.

$$f(t, y)(s) = \sup\{y(r) / s = f(t, r)\}, s \in R.$$

It follows that;

$$[f(t, y)]_r = [f_1(t, y; r), f_2(t, y; r)], r \in (0, 1]$$

Where





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$$f_1(t, y; r) = \min \{ f(t, u) / u \in y_1(r), y_2(r) \}$$

$$f_2(t, y; r) = \max \{ f(t, u) / u \in y_1(r), y_2(r) \}$$

Runge – Kutta Method for Problems with Initial Values

The problem with initial values is,

$$\begin{cases} y'(t) = f(t, y(t)); a \leq t \leq b \\ y(a) = \alpha, \end{cases} \tag{3.1}$$

The basis of all Runge-Kutta method is to express the difference between the value of y at t_{n+1} and t_n as

$$y_{n+1} - y_n = \sum_{i=1}^m w_i k_i \tag{3.2}$$

where for $i=1, 2, \dots, m$, w_i 's are constants and $k_i = hf(t_n + c_i h, y_n + \sum_{j=1}^{i-1} a_{ij} k_j)$ (3.3)

Equations (3.2) is to be exact for powers of h through h^m , because it is to be coincident with Taylor series of order m.

THE NOVEL RUNGE - KUTTA METHOD OF ORDER 4 WITH THE COMBINATION OF AM, GM AND RTMS FOR DIFFERENTIAL EQUATIONS OF FIRST ORDER

For the IVP of the form

$$Y' = f(t, y),$$

the Fourth order Runge - Kutta methods ([2] and [4]) using variety of means can be written in the form

$$Y_{n+1} = y_n + \frac{h}{2} \left[\sum_{i=1}^4 Mean \right] \tag{3.4}$$

where means includes Arithmetic Mean(AM), Geometric Mean (GM), Contraharmonic Mean (CoM), Centroidal Mean (CeM), Root Mean Square (RM), Harmonic Mean(HaM), and Heronian Mean (HeM) which involves k_i , where

$$k_1 = f(t_n, y_n)$$

$$k_2 = f(t_n + a_1, y_n + a_1 h k_1)$$

$$k_3 = f(t_n + (a_2 + a_3), y_n + a_2 h k_1 + a_3 h k_2)$$

$$k_4 = f(t_n + (a_3 + a_4), y_n + a_2 h k_1 + a_3 h k_2 + a_4 h k_3)$$

with the grid points $a = t_0 \leq t_1 \leq \dots \leq t_N = b$ and $h = \frac{b-a}{N} = t_{i+1} - t_i$ (3.5)

Consider an Initial Value Problem (IVP), which can be written in the form

$$y'(t) = f(t, y(t)), y(t_0) = y_0 \tag{3.6}$$

The autonomous structure for (3.7) is

$$y'(t) = f(y(t)), y(t_0) = y_0 \tag{3.8}$$

A classical fourth order of Runge-Kutta method to solve (3.6) as follows

$$y_{n+1} = y_n + \frac{h}{6} (k_1 + 2k_2 + 2k_3 + k_4), \tag{3.9}$$

Where





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$$\begin{aligned}
 k_1 &= f(t_n, y_n) \\
 k_2 &= f\left(t_n + \frac{h}{2}, y_n + \frac{h}{2}k_1\right) \\
 k_3 &= f\left(t_n + \frac{h}{2}, y_n + \frac{h}{2}k_2\right) \\
 k_4 &= f(t_n + h, y_n + hk_3)
 \end{aligned}
 \tag{3.10}$$

Since the formula (3.6) can be written in the form

$$y_{n+1} = y_n + \frac{h}{2} \left(\frac{k_1 + k_2}{2} + \frac{k_2 + k_3}{2} + \frac{k_3 + k_4}{2} \right)
 \tag{3.11}$$

then the method (3.6) is also named as Runge –Kutta method based on an Arithmetic Mean. This formula is modified by replacing Arithmetic Mean with Geometric mean.

$$\begin{aligned}
 k_1 &= f(t_n, y_n) \\
 k_2 &= f\left(t_n + \frac{1}{2}h, y_n + \frac{1}{2}hk_1\right) \\
 k_3 &= f\left(t_n + \frac{1}{2}h, y_n + \frac{h}{16}[-k_1 + 9k_2]\right) \\
 k_4 &= f\left(t_n + h, y_n + \frac{h}{24}[-3k_1 + 5k_2 + 22k_3]\right) \\
 y_{n+1} &= y_n + \frac{h}{3} \left(\sqrt{k_1k_2} + \sqrt{k_2k_3} + \sqrt{k_3k_4} \right)
 \end{aligned}
 \tag{3.12}$$

And (3.6) is also modified by replaced an Arithmetic mean with a Root mean square.

$$y_{n+1} = y_n + \frac{h}{3} \left(\sqrt{\frac{k_1^2k_2^2}{2}} + \sqrt{\frac{k_2^2k_3^2}{2}} + \sqrt{\frac{k_3^2k_4^2}{2}} \right)
 \tag{3.13}$$

Substituting the Arithmetic mean, Geometric mean and Root mean square in this above equation ,we arrived at the Runge-Kutta method of order 4 with combination of Am, Gm And Rtms in Khattri [14] as follow

$$RM(k_1, k_2) = \frac{14AM(k_1, k_2) - GM(k_1, k_2) + 32RM(k_1, k_2)}{45}$$

After substituting the Arithmetic mean, Geometric mean and Root mean square in this above equation, we arrived at the following formula :

$$y_{n+1} = y_n + \frac{h}{135} \left\{ \begin{aligned} &7(k_1 + 2(k_2 + k_3) + k_4) - (\sqrt{k_1k_2} + \sqrt{k_2k_3} + \sqrt{k_3k_4}) + \\ &32\left(\sqrt{\frac{k_1^2k_2^2}{2}} + \sqrt{\frac{k_2^2k_3^2}{2}} + \sqrt{\frac{k_3^2k_4^2}{2}}\right) \end{aligned} \right\}
 \tag{3.14}$$

Where





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$$\begin{aligned}
 k_1 &= f(x_n, y_n) \\
 k_2 &= f(x_n + 0.5h, y_n + 0.5hk_1) \\
 k_3 &= f(x_n + 0.5h, y_n + 0.04583hk_1 + 0.45417hk_2) \\
 k_4 &= f(x_n + h, y_n + 0.09168hk_1 - 0.21109hk_2 + 1.11941hk_3)
 \end{aligned}$$

The Runge - Kutta method of order 4 with Am, Gm And Rtms as combination for uncertain differential equations of first order

Let us consider the first order fuzzy ordinary differential equations of the form

$$\begin{cases}
 y'(t) = f(t, y) \\
 y(t_0) = y_0
 \end{cases} \tag{4.1}$$

The equations (2) and (3) are exact and approximate solutions of equation (4.1) respectively

$$[Y(t_n)]_r = [\underline{Y}(t_n; r), \bar{Y}(t_n; r)] \tag{4.2}$$

$$[y(t_n)]_r = [\underline{y}(t_n; r), \bar{y}(t_n; r)] \tag{4.3}$$

By using Fourth order Runge-Kutta method the approximate solution is obtained as follows

$$[\underline{y}(t_{n+r}; r)]_r = \underline{y}(t_n; r) + \sum_{j=1}^4 u_j k_{j,1}(t_n, y(t_n; r)) \tag{4.4}$$

$$[\bar{y}(t_{n+r}; r)]_r = \bar{y}(t_n; r) + \sum_{j=1}^4 u_j k_{j,1}(t_n, y(t_n; r))$$

Where the u_i 's are constants and

$$\begin{aligned}
 [k_i(t, y(t; r))]_r &= [\underline{k}_i(t, y(t; r)), \bar{k}_i(t, y(t; r))], i = 1, 2, 3 \\
 \underline{k}_i(t_n, y(t_n; r)) &= h.f(t_n + c_i h, \underline{y}(t_n) + \sum_{j=1}^{i-1} a_{ij} \underline{k}_j(t_n, y(t_n; r))) \\
 \bar{k}_i(t_n, y(t_n; r)) &= h.f(t_n + c_i h, \bar{y}(t_n) + \sum_{j=1}^{i-1} a_{ij} \bar{k}_j(t_n, y(t_n; r))).
 \end{aligned} \tag{4.5}$$

$$\begin{aligned}
 k_{1,1}(t_n, y(t_n; r)) &= \min h \{ f(t_n, v) / v \in (\underline{y}(t_n; r), \bar{y}(t_n; r)) \} \\
 k_{1,2}(t_n, y(t_n; r)) &= \max h \{ f(t_n, v) / v \in (\underline{y}(t_n; r), \bar{y}(t_n; r)) \} \\
 k_{2,1}(t_n, y(t_n; r)) &= \min h \{ f(t_n + 0.5h, v) / v \in p_{1,1}(t_n, y(t_n; r)), p_{1,2}(t_n, y(t_n; r)) \} \\
 k_{2,2}(t_n, y(t_n; r)) &= \max h \{ f(t_n + 0.5h, v) / v \in p_{1,1}(t_n, y(t_n; r)), p_{1,2}(t_n, y(t_n; r)) \} \\
 k_{3,1}(t_n, y(t_n; r)) &= \min h \{ f(t_n + 0.5h, v) / v \in p_{2,1}(t_n, y(t_n; r)), p_{2,2}(t_n, y(t_n; r)) \} \\
 k_{3,2}(t_n, y(t_n; r)) &= \max h \{ f(t_n + 0.5h, v) / v \in p_{2,1}(t_n, y(t_n; r)), p_{2,2}(t_n, y(t_n; r)) \} \\
 k_{4,1}(t_n, y(t_n; r)) &= \min h \{ f(t_n + h, v) / v \in p_{3,1}(t_n, y(t_n; r)), p_{3,2}(t_n, y(t_n; r)) \} \\
 k_{4,2}(t_n, y(t_n; r)) &= \max h \{ f(t_n + h, v) / v \in p_{3,1}(t_n, y(t_n; r)), p_{3,2}(t_n, y(t_n; r)) \}
 \end{aligned} \tag{4.6}$$

Where in the fourth order Runge-Kuuta method with combination of Am, Gm And Rtms is as follows





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$$\begin{aligned}
 p_{1,1}(t_n, y(t_n; r)) &= \underline{y}(t_n; r) + 0.5hk_{1,1}(t_n, y(t_n; r)) \\
 p_{1,2}(t_n, y(t_n; r)) &= \underline{y}(t_n; r) + 0.5hk_{1,2}(t_n, y(t_n; r)) \\
 p_{2,1}(t_n, y(t_n; r)) &= \underline{y}(t_n; r) + 0.04583hk_{2,1}(t_n, y(t_n; r)) + 0.45417hk_{2,2}(t_n, y(t_n; r)) \\
 p_{2,2}(t_n, y(t_n; r)) &= \underline{y}(t_n; r) + 0.04583hk_{2,1}(t_n, y(t_n; r)) + 0.45417hk_{2,2}(t_n, y(t_n; r)) \\
 p_{3,1}(t_n, y(t_n; r)) &= \underline{y}(t_n; r) + 0.09168hk_{3,1}(t_n, y(t_n; r)) - 0.21109hk_{3,2}(t_n, y(t_n; r)) + 1.11941hk_{3,3}(t_n, y(t_n; r)) \\
 p_{3,2}(t_n, y(t_n; r)) &= \underline{y}(t_n; r) + 0.09168hk_{3,1}(t_n, y(t_n; r)) - 0.21109hk_{3,2}(t_n, y(t_n; r)) + 1.11941hk_{3,3}(t_n, y(t_n; r))
 \end{aligned}$$

Define,

$$F(t, y(t; r)) = \frac{h}{135} \left\{ \begin{aligned} &7(\underline{k}_1(t, y(t; r)) + 2(\underline{k}_2(t, y(t; r)) + \underline{k}_3(t, y(t; r)) + \underline{k}_4(t, y(t; r))) - \\ &(\sqrt{\underline{k}_1(t, y(t; r))\underline{k}_2(t, y(t; r))} + \sqrt{\underline{k}_2(t, y(t; r))\underline{k}_3(t, y(t; r))} + \sqrt{\underline{k}_3(t, y(t; r))\underline{k}_4(t, y(t; r))}) + \\ &32(\sqrt{\frac{\underline{k}_1^2(t, y(t; r))\underline{k}_2^2(t, y(t; r))}{2}} + \sqrt{\frac{\underline{k}_2^2(t, y(t; r))\underline{k}_3^2(t, y(t; r))}{2}} + \sqrt{\frac{\underline{k}_3^2(t, y(t; r))\underline{k}_4^2(t, y(t; r))}{2}}) \end{aligned} \right\}$$

$$G(t, y(t; r)) = \frac{h}{135} \left\{ \begin{aligned} &7(\bar{k}_1(t, y(t; r)) + 2(\bar{k}_2(t, y(t; r)) + \bar{k}_3(t, y(t; r)) + \bar{k}_4(t, y(t; r))) - \\ &(\sqrt{\bar{k}_1(t, y(t; r))\bar{k}_2(t, y(t; r))} + \sqrt{\bar{k}_2(t, y(t; r))\bar{k}_3(t, y(t; r))} + \sqrt{\bar{k}_3(t, y(t; r))\bar{k}_4(t, y(t; r))}) + \\ &32(\sqrt{\frac{\bar{k}_1^2(t, y(t; r))\bar{k}_2^2(t, y(t; r))}{2}} + \sqrt{\frac{\bar{k}_2^2(t, y(t; r))\bar{k}_3^2(t, y(t; r))}{2}} + \sqrt{\frac{\bar{k}_3^2(t, y(t; r))\bar{k}_4^2(t, y(t; r))}{2}}) \end{aligned} \right\}$$

The exact and approximate solutions of at $t_n, 0 \leq n \leq N$ are denoted by

$$[Y(t_n)]_r = [\underline{Y}(t_n; r), \bar{Y}(t_n; r)] \tag{4.5}$$

$$[y(t_n)]_r = [\underline{y}(t_n; r), \bar{y}(t_n; r)] \tag{4.6}$$

By (4.1) and (4.5) we get the exact value as

$$\underline{y}_{n+1}(r) \approx \underline{y}(t_n; r) + \frac{h}{2} F[t_n, Y(t_n; r)] \tag{4.7}$$

$$\bar{y}_{n+1}(r) \approx \bar{y}(t_n; r) + \frac{h}{2} G[t_n, Y(t_n; r)]$$

The approximate solution is given by





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$$\begin{aligned} \underline{y}(t_{n+1}; r) &\approx \underline{y}(t_n; r) + \frac{h}{2} F[t_n, Y(t_n; r)] \\ \bar{y}(t_{n+1}; r) &\approx \bar{y}(t_n; r) + \frac{h}{2} G[t_n, Y(t_n; r)] \end{aligned} \tag{4.8}$$

NUMERICAL EXAMPLES

Example :5.1 Consider the fuzzy initial value problem,

$$\begin{cases} y^1(t) = y(t), t \in [0,1] \\ y(0) = (0.75 + 0.25r, 1.125 - 0.125r), 0 < r \leq 1. \end{cases}$$

The exact solution is given by

$$\underline{Y}(t; r) = \underline{y}(t; r)e^t, \bar{Y}(t; r) = \bar{y}(t; r)e^t \text{ which at } t=1 \text{ is}$$

$$Y(1; r) = [(0.75 + 0.25r)e, (1.125 - 0.125r)e], 0, r \leq 1.$$

The exact and approximate solution obtained by the newly proposed method using the Fourth order Runge –Kutta method based on linear combination of Arithmetic mean Geometric mean and Root mean when h= 0.1, t=1 is displayed in table (1)

Example 5.2 :

Consider the fuzzy initial value problem,

$$\begin{cases} y^1(t) = y(t), t \in [0,1] \\ y(0) = (0.8 + 0.125r, 1.1 - 0.1r), 0 < r \leq 1. \end{cases}$$

The exact solution is given by

$$\underline{Y}(t; r) = \underline{y}(t; r)e^t, \bar{Y}(t; r) = \bar{y}(t; r)e^t \text{ which at } t=1 \text{ is}$$

$$Y(1; r) = [(0.8 + 0.125r)e^t, (1.1 - 0.1r)e^t], 0, r \leq 1.$$

Example 5.3:

Consider the fuzzy initial value problem

$$\begin{cases} y^1(t) = tf(t) \\ y(-1) = (\sqrt{e} - 0.5(1 - r), \sqrt{e} + 0.5(1 - r)) \end{cases}$$

When $t \geq 0$

The exact solution at $t_0 = 0.1$ is given by

$$Y_1(t; r) = y_1(0; r)e^{\frac{t^2}{2}}$$

$$Y_2(t; r) = y_2(0; r)e^{\frac{t^2}{2}}$$

Example 5.4

Consider the fuzzy initial value problem





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$$\begin{cases} y^1(t) = tf(t) \\ y(0) = (1.01 + 0.1r\sqrt{e}, 1.5 + 0.1r\sqrt{e}) \end{cases}$$

The exact solution at $t_0 = 0.1$ is given by $Y(0.1 : r) = [(1.01 + 0.1r\sqrt{e})e^{0.005}, (1.5 + 0.1r\sqrt{e})e^{0.005}]$, $0 \leq r \leq 1$

The exact and approximate solutions using the proposed method when $h = 0.1$, $t = 0.1$ is shown below.

CONCLUSIONS

In this study, we employed the fourth-order Runge-Kutta method, incorporating a combination of Arithmetic Mean (AM), Geometric Mean (GM), and Root Mean Square (RTMS), to numerically solve first-order fuzzy differential equations using both trapezoidal and triangular fuzzy numbers. In Example 1, when $h = 0.1$ and $t = 1$, the error between the approximate and exact values is significantly small. In Example 2, using our innovative method with the same parameters ($h = 0.1$ and $t = 1$), we also observed a negligible error between the approximate and exact values. Similarly, in Example 3 and Example 4, when $h = 0.1$ and $t = 0.1$, both the approximate and exact values closely align, as depicted in figures 5.1 and 5.2. By comparing the exact and approximate values, it is evident that our proposed fourth-order Runge-Kutta method, featuring the combination of AM, GM, and RTMS, consistently yields minimized error values. This underscores the effectiveness of our approach in providing improved solutions for these fuzzy differential equations.

REFERENCES

1. Abbasbandy. S, T. Allahviranloo, 'Numerical solutions of fuzzy differential equations by Taylor method', *Comput. Methods Appl. Math.* 2 (2002) 113-124.
2. Abbasbandy. S, T. Allahviranloo, Oscar Lopez-Pouso, J.J. Nieto, 'Numerical Methods for Fuzzy Differential Inclusions', *Comput. Math. Appl.* 48 (2004) 1633-1641.
3. Allahviranloo. T, N. Ahmady, E. Ahmady, 'Numerical solution of fuzzy differential equations by Predictor-Corrector method', *Infor. Sci.* 177 (2007) 1633-1647.
4. Alexander. R.K and Coyle. J.J. (1990), 'Runge-Kutta methods for different algebraic systems', *SIAM Journal of Numerical Analysis*, Vol 27, No.3, pp. 736-752.
5. Buckley. J.J, T. Feuring, 'Fuzzy differential equations', *Fuzzy Sets and Systems* 110 (2000) 43-54.
6. Buckley. J.J, T. Feuring, 'Fuzzy Initial Value Problem for Nth-order fuzzy linear differential equations', *Fuzzy Sets and Systems* 121 (2001) 247-255.
7. Bede.B. and Gal, S.G Generalizations of the differentiability of fuzzy number valued functions with applications to fuzzy differential equation, *Fuzzy Sets and Systems* 151, 581 – 599, 2005.
8. Bede. B., Rudas, I.J. and Bencsik, A.L. First order linear fuzzy differential equations under generalized differentiability, *Inform.Sci.* 177, 1648-1662, 2007.
9. Chang. S.L, L.A. Zadeh, 'On fuzzy mapping and control', *IEEE Trans. Systems Man Cyber-net*, 2 (1972) 30-34.
10. Dubois. D, H. Prade, 'Towards fuzzy differential calculus', Part 3: Differentiation, *Fuzzy Sets and Systems* 8 (1982) 225-233.
11. Evans. D.J. and Yaakub. A.R. (1995), 'A New Fourth Order Runge-Kutta Formula based on the Contra-Harmonic Mean', *Intern.J. Computer Math* 57, 249-256.
12. Evans. D.J. and Yaakub. A.R. (2002), 'A Fifth Order Runge-Kutta R.K(5,5) Method with Error Control'. *Intern J. Computer Math*, 79. 1179-1185
13. Evans. D.J. and Yaakub. A.R. (1995), 'A New Fifth Order Weighted Runge-Kutta Formula', *Intern.J. Computer Math* 59, 227-243.





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14. GethsiSharmila.R and E.C. Henry Amirtharaj, 'Numerical Solution of Fuzzy Initial Value Problems by Fourth Order Runge-Kutta Method Based on Conharmonic Mean', *Indian Journal of applied research* 3(4) (2013) 339-343.
15. Kandel. A, W.J. Byatt, 'Fuzzy differential equations', in *Proceedings of the International Conference on Cybernetics and Society, Tokyo, (1978)* 1213-1216.
16. 16.Khattri S.K., (2012), Euler's Number and Some Means, *Tamsui Oxford Journal of Information and Mathematical Sciences*,pp.369-377.
17. Ming Ma, Friedman.M, and Kandel.A, Numerical solutions of fuzzy differential equations, *Fuzzy Sets and Systems*, 105 (1999), 35-48.
18. Puri. M.L, D.A. Ralescu, 'Differentials of Fuzzy Functions', *J. Math. Anal. Appl.* 91 (1983) 552-558.
19. 19. Seikkala. S, 'On the fuzzy initial value problem', *Fuzzy Sets and Systems*24 (1987) 319- 330.
20. V.Nirmala,N.Saveetha,S.Chenthurpandiyar,(2010) "Numerical Solution of Fuzzy Differential Equations by Runge-Kutta Method with Higher order Derivative Approximations",*Proceedings of the International conference on Emerging Trends in Mathematics and Computer Applications,India:MEPCO schlenk Engineering College,Sivakasi Tamilnadu,pp.131-134(ISBN:978-81-8424-649-0)*
21. Palligkinis, S.Ch.,G.Papageorgiou,Famelis,I.TH.(2009)," Runge-Kutta methods for fuzzy differential equations", *Applied Mathematics Computation*, 209,pp.97-105.
22. R.Ponalagusamy and S.Senthilkumar, A New Fourth Order Embedded RKAHeM(4,4) method with Error Control on Multilayer Raster Cellular Neural Network, *Signal Image and Video Processing*, 2008[Accepted in Press].

Table 1: (The approximate, exact and absolute error table for ex 6.1 when h=0.1, t=1)

R	T	\underline{y}	\bar{y}	\underline{Y}	\bar{Y}	Error between \underline{y} and \underline{Y}	Error between \bar{y} and \bar{Y}
0.0	1.000000	2.038711	3.058067	2.038711	3.058067	2.132220e-07	3.198330e-07
0.100000	1.000000	2.106668	3.024088	2.106668	3.024089	2.203294e-07	3.162793e-07
0.200000	1.000000	2.174625	2.990110	2.174625	2.990110	2.274368e-07	3.127256e-07
0.300000	1.000000	2.242582	2.956131	2.242583	2.956131	2.345442e-07	3.091719e-07
0.400000	1.000000	2.310539	2.922153	2.310540	2.922153	2.416516e-07	3.056182e-07
0.500000	1.000000	2.378496	2.888174	2.378497	2.888174	2.487590e-07	3.020645e-07
0.600000	1.000000	2.446453	2.854196	2.446454	2.854196	2.558664e-07	2.985108e-07
0.700000	1.000000	2.514410	2.820217	2.514411	2.820217	2.629738e-07	2.949571e-07
0.800000	1.000000	2.582367	2.786239	2.582368	2.786239	2.700812e-07	2.914034e-07
0.900000	1.000000	2.650325	2.752260	2.650325	2.752260	2.771886e-07	2.878497e-07
1.000000	1.000000	2.718282	2.718282	2.718282	2.718282	2.842960e-07	2.842960e-07





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Table 2:(The approximate, exact and absolute error table for ex 5.2 when h=0.1, t=1)

R	t	\underline{y}	\bar{y}	\underline{Y}	\bar{Y}	Error between \underline{y} and \underline{Y}	Error between \bar{y} and \bar{Y}
0.000000	1.000000	2.174625	2.990110	2.174625	2.990110	2.274368e-07	3.127256e-07
0.100000	1.000000	2.208604	2.962927	2.208604	2.962927	2.309905e-07	3.098826e-07
0.200000	1.000000	2.242582	2.935744	2.242583	2.935744	2.345442e-07	3.070397e-07
0.300000	1.000000	2.276561	2.908561	2.276561	2.908562	2.380979e-07	3.041967e-07
0.400000	1.000000	2.310539	2.881378	2.310540	2.881379	2.416516e-07	3.013538e-07
0.500000	1.000000	2.344518	2.854196	2.344518	2.854196	2.452053e-07	2.985108e-07
0.600000	1.000000	2.378496	2.827013	2.378497	2.827013	2.487590e-07	2.956678e-07
0.700000	1.000000	2.412475	2.799830	2.412475	2.799830	2.523127e-07	2.928249e-07
0.800000	1.000000	2.446453	2.772647	2.446454	2.772647	2.558664e-07	2.899819e-07
0.900000	1.000000	2.480432	2.745464	2.480432	2.745465	2.594201e-07	2.871390e-07
1.000000	1.000000	2.514410	2.718282	2.514411	2.718282	2.629738e-07	2.842960e-07

Table 3: (The approximate, exact and absolute error table for ex 5.3 when h=0.1, t=0.1)

R	T	\underline{y}	\bar{y}	\underline{Y}	\bar{Y}	Error between \underline{y} and \underline{Y}	Error between \bar{y} and \bar{Y}
0	0.1	1.015429	1.508063	1.015063	1.507519	3.667750e-04	5.447153e-04
0.1	0.1	1.032005	1.524639	1.031633	1.524089	3.727622e-04	5.507025e-04
0.2	0.1	1.048581	1.541215	1.048202	1.540658	3.787494e-04	5.566897e-04
0.3	0.1	1.065157	1.557791	1.064772	1.557228	3.847366e-04	5.626770e-04
0.4	0.1	1.081733	1.574367	1.081342	1.573798	3.907239e-04	5.686642e-04
0.5	0.1	1.098309	1.590943	1.097912	1.590368	3.967111e-04	5.746514e-04
0.6	0.1	1.114884	1.607519	1.114482	1.606938	4.026983e-04	5.806386e-04
0.7	0.1	1.131460	1.624094	1.131052	1.623508	4.086855e-04	5.866259e-04
0.8	0.1	1.148036	1.640670	1.147621	1.640078	4.146728e-04	5.926131e-04
0.9	0.1	1.164612	1.657246	1.164191	1.656647	4.206600e-04	5.986003e-04
1	0.1	1.181188	1.673822	1.180761	1.673217	4.266472e-04	6.045875e-04





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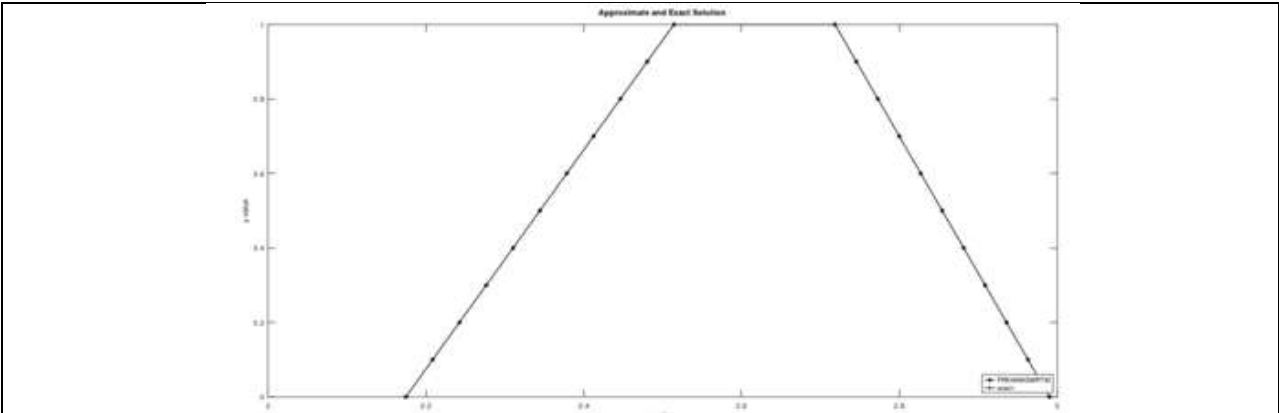


Figure 1(Comparison between approximate and Exact values Example5.2)

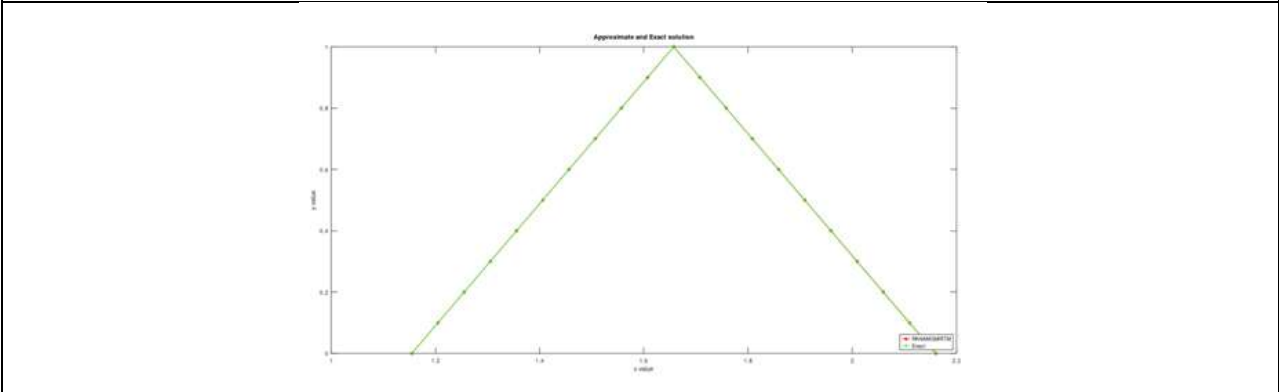


Figure 2 (Comparison between approximate and Exact values for Ex5.3)





***In vitro* and *In-silico* Study of the Plant Extract of *Barleria lupulina* with the Evaluation of it's Antibacterial and Antioxidant Properties**

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ABSTRACT

The disc diffusion assay was used in this study to determine the *in vitro* antibacterial activity of the chloroform extract of *Barleria lupulina* leaves against a number of pathogenic bacterial strains. Moderately significant antibacterial activity was found when comparing the zone of inhibition produced by plant chloroform extracts to conventional antibiotic discs. MIC has been evaluated as well. Gallic acid was used as the standard in the study of the total phenol content and was quantitatively estimated using the Folin-Ciocalteu method. The assay for antioxidants has also been done using the peroxide method. The physicochemical characteristics of the herbal extract were taken into consideration during formulation. The molecular docking of the reported phytochemicals with the enzyme was examined using Biovia Discovery Studio. The HDock server was used to determine the interaction's strength. The model that had the significant confidence values after the docking process and optimum docking score values showed efficient ligand receptor binding.

Keywords: *In-silico* study, HDock, Phenolic content, Folin- Ciocalteu method, *Barleria lupulina*.





INTRODUCTION

The French botanist and Dominican friar Jacques Barrelier is the source of the genus name Barleria. The following Barleria species are used traditionally for a range of ethnomedical properties: *B. cristata*, *B. optusa*, *B. prionitis*, *B. acanthoides*, *B. aculeata*, *B. albostellata*, *Barleria greenii*, *B. repens*, *B. tetraacantha*, *B. strigosa*, and *B. lupulina*. *Barleria lupulina* has different names depending on where it is found. The common names for *B. lupulina* include Hophead Philippine violet, Kanta Vishalyakarni in Bengali, Neel Saireyak in Sanskrit, etc. It has a variety of medical qualities, such as antibacterial and anti-inflammatory effects [1], antecedent [2]. HSV-2, anti-clastogenic, anti-tumour, and [3-4], immunomodulatory, and anti-diabetic[5]. According to some sources [6], the *B. lupulina* plant also produces a number of iridoid glucosides, batakine, and alkaloids. The leaves of this plant are traditionally used to treat swelling, bleeding wounds, rheumatism, dog bites, snake bites, and snake bites. The overuse of antibiotics has sparked the emergence of multi-drug resistance in bacterial diseases all over the world. Traditional medicinal plants must be used as an alternative to pharmaceuticals to treat a variety of ailments. Since there is a lack of scientific evidence, the experimental work in this study has been focused on the antioxidation and antibacterial test of chloroform extract of *Barleria lupulina*.

MATERIALS AND METHODS

MATERIALS

The extraction procedure made use of methanol (Merck, India), ethanol (Lobachem, India), and chloroform (Lobachem, India). The phenolic content of the extract was estimated using gallic acid (Lobachem, India), the Folin-Ciocalteu Reagent (Lobachem, India), and hydrogen peroxide (Merck, India) was employed for the peroxide method of antioxidant research. The formulation of the herbal extract included the following ingredients: hydroxypropyl methyl cellulose (Lobachem, India), propylene glycol (Lobachem, India), propyl paraben (Lobachem, India), and methyl paraben (Lobachem, India). Chloroform extracts were tested against a panel of 4 pathogenic bacterial strains including *Staphylococcus aureus* MTCC 96, *Bacillus subtilis* MTCC 441, *Escherichia coli* MTCC 443 and *Pseudomonas aeruginosa* MTCC 424 were purchased from Institute of Microbial Technology, Sector 39, Chandigarh, India.

Collection and Extraction of plant material

The plant sample, which consisted of leaves, was gathered from an herbal garden in Shyamnagar, West Bengal. It was then air dried in the shade at room temperature, grounded into a fine powder with an electric grinder, and then stored in an airtight container for future use. For extraction, the powdered sample was combined with solvents in a 4:1 methanol to water ratio. The substance was then filtered using Whatman No. 1 filter paper, and the filtrate was combined with (2–3) drops of 2M HCl before being combined with an equivalent volume of chloroform. The dried residue was obtained by taking the lowest organic layer after it had formed, separating it, and then letting the solvent evaporate. The resulting chloroform extract solution was used for further antibacterial and antioxidant activity [7].

Phytochemical screening of Extract

Terpenoids Test: The Salkowski test determines the presence of triterpenoid by forming a reddish-brown colour at the interface when dry extract is combined with water and a few drops of concentrated H₂SO₄.

Alkaloids Test: A good outcome is indicated by the production of a reddish-brown precipitate after adding 1 ml of Dragandroff's reagent to 2 ml of the filtrate.

Wagner's test: When 2 ml of extract are combined with a few drops of Wagner's reagent, a reddish brown precipitate forms to indicate a successful reaction.

Hager's test: A positive result is shown by the production of a yellow-colour precipitate when 2 ml of extract is combined with a few drops of Hager's reagent.



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Mayer's test: A positive result is confirmed if a creamy precipitate forms after mixing 2 ml of extract with a few drops of Mayer's reagent.

Glycosides Test: If the extract yields a positive result in either of the Fehling (Fehling test A and Fehling test B) solutions, glycosides are present.

Flavonoids Test:

Ammonium test: Layer separation was possible when the extract filtrate was combined with a diluted (1 ml, 1% v/v) ammonia solution. A favourable outcome is indicated if the ammonia layer is yellow.

Alkaline test: A favourable outcome is indicated by the dark yellow substance that turns colourless when diluted hydrochloric acid is added to the extract (2 ml) after being treated with a few drops of a 20% (w/v) sodium hydroxide solution.

Steroids Test

Salkowski test: A positive result was achieved when 2 ml of extract, 2 ml of chloroform, and 2 ml of concentrated sulphuric acid were added. If the chloroform layer was red and the acid layer was yellow-green fluorescence, the test was successful. **Ferric chloride test for phenols:** If the extract was treated with 3–4 drops of a 10% (w/v) ferric chloride solution and the appearance of a black green colour was noted, phenolic compound was present [8].

Quantitative analysis of total Phenolic content

The Folin-Ciocalteu reagent was used to determine the total phenolic analysis of the extracts quantitatively. Gallic acid served as the analytical standard whose concentration (10–50 mg/ml) was produced in methanol. Plant extract at a concentration of 1 mg/ml was produced in methanol, and then 0.5 mg of the sample was added to test tubes together with 2 mg of the Folin-Ciocalteu reagent and 2 mg of the 10% sodium carbonate solution. The tube was covered and let to stand at room temperature for 30 minutes before the absorbance at 760 nm was spectrophotometrically measured. The Folin-Ciocalteu reagent reacts with reducing substances, such as polyphenols, and gives off a blue colour as a result. The spectrophotometric measurement of this blue hue. In light of this, the total phenolic content was established [9].

Antioxidant activity of the plant extract

The ability of plant extracts to scavenge hydrogen peroxide can be estimated according to the peroxide method. A solution of hydrogen peroxide (40 mM) is prepared in phosphate buffer (50 mM pH 7.4). The absorbance of hydrogen peroxide is determined by absorption at 230 nm using a spectrophotometer. Extract (100 µg/mL) in distilled water is added to hydrogen peroxide and absorbance at 230 nm is determined after 10 min against a blank solution containing phosphate buffer without hydrogen peroxide. The percentage of hydrogen peroxide scavenging is calculated as follows

$$\% \text{ scavenged (H}_2\text{O}_2) = (A_0 - A_1)/A_0 \times 100$$

Where A_0 is the absorbance of the control and A_1 the absorbance of the sample [10].

ANTIMICROBIAL ASSESSMENT**Broth dilution method**

The minimum inhibitory concentration (MIC) was determined using the broth dilution method as described by a specific method [11]. Concentrations of extracts (1-9 mg mL⁻¹) dilutions were prepared using tubes containing 9 ml of double strength broth. In all test tubes, test antimicrobial compound is added except uninoculated (negative control) and control (positive) tube. The positive control tube is to check for the suitability of the test microorganism and the viability of the inoculums. The final volume was adjusted in all tubes by using sterile water. The tubes were inoculated with the suspension of standardized inocula (0.5 McFarland standard) and incubated at 37°C for 24 h. MIC was recorded as the lowest concentration of extract showing no visible bacterial growth.

Disc diffusion method



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The disc diffusion assay was used to screen for antibacterial activity as described by the scientists [12]. The standard inoculum was introduced onto the surface of the sterile agar plates and a sterile glass spreader was used for even distribution over the media. Blank sterile paper discs (6 mm) were placed on the inoculated Mueller-Hinton agar surface and impregnated with 50 μ L of the different extracts. A concentration of 10 μ g/disc of Streptomycin (Sigma Aldrich, India), was used as a standard. The procedure was repeated for all the selected bacterial species used. The plates were incubated at 37°C for 24 h. All tests were performed in triplicate and the antibacterial activity was expressed as the mean diameter of inhibition zones (mm) produced by the extracts. *In-silico* study Molecular docking method has been used to identify the phytochemical from the plant extract that act as a ligand and form a strong covalent bond with the microbial protein to successfully inhibit the microbe. The discovery studio module of the biovia software is using for identify molecular interaction and perform molecular docking. In this process, first the pdb files for the phytochemicals (Phytol) found in the Barleria lupulina plant were downloaded from the website drug bank .The protein DNA gyrase DNA binding domain makes complex with a small molecule inhibitor data base code (6FM4) was collected from RCSB protein data bank. Molecular docking was done by using the HDock Server. The enzyme molecule was treated as the receptor molecule and the phytochemical was treated as the ligand. The high positive values (Low negative Docking score) and more confidence score are the indicators can be presented as the good interaction between the ligand and the receptor. Thus, the interaction with high values might indicate the major phytochemical responsible for curing the disease. Phytol inhibit the activity of *S. aureus* by blocking the potential effect of DNA gyrase simulation in DNA binding sites [13].

Method of formulation of herbal extract gel

The required amount of gelling agent was accurately measured and dispersed in a small amount of water with continuous stirring to produce a uniform dispersion. Then the drug was dissolved in a suitable solvent here using propylene glycol and added to the above dispersion. Other substances such as methyl paraben and propyl paraben were also added with continuous stirring. The final weight of the gel formulation was adjusted to 10 g with distilled water. The gel was stored in container with wide mouth.

Evaluation of gel formulation**Physical Characterizations**

The composition of gel using different gelling agents tested for colour, odour, homogeneity, in which the gels were placed in containers.

Measurement of Surface pH

The pH formation of gel was measured using a digital pH meter. 1 g of gel was dissolved in 25 ml of distilled water in a beaker. The electrode was then immersed in the beaker solution and allowed to simmer for 1 minute and further reading was observed.

Spreadability

Indicates the level of area where the gel spreads easily when applied to the affected skin. The therapeutic potential of the gel also depends on its spreading value. It is periodically displayed in seconds taken by two slides to move from the gel placed between the slides under the direction of a specific load (20 g).

The formula for calculating gel spreadability is: $S = M * (L / T)$

Where,

M = Weight tied to the top slide (20 g)

L = Length of the glass slide slipped

T = Time taken to split the slides.

Tube Extrudability

In this experiment was taken a closed folding tube containing the composition of the ciprofloxacin gel. The gel was pressed tight at the end and a clamp was placed at the end of the tube to prevent any loosening. A weight of 500 g was placed on tube and removed from the cap. The gel was pulled out.





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The formula for calculating tube extrudability is: $E = (M / A)$

Where,

E = Tube extrudability

M = Weight applied on tube (500 g)

A = Extrude gel area [14].

RESULTS AND DISCUSSIONS

Phytochemical Screening

D= Dragandroff's reagent

M= Mayer's reagent

H= Hager's reagent

W= Wagner's reagent

(+) signify positive result

(-) signify negative result

The result showed that the chloroform extract has primarily flavonoids and phenolic part which is generally important for antibacterial and antioxidant activity. *Ocimum tenuiflorum* was used as positive control to find out the validity of the reagent used for phytochemical screening.

Quantitative estimation of phenolic content

The absorbance value of the plant material is 0.954, Now by plotting the value on the equation the conc. was found out to be is 55.14 ug/ml.

Antioxidant assessment

Percent Scavenged; % (H_2O_2) = $[(A_0 - A_1) / A_0 \times 100]$

A_0 = absorbance of Control = 0.415

A_1 = the absorbance of plant sample = 0.25.

$0.415 - 0.25 / 0.415 \times 100 = 39.76\%$.

Note

The control disc used for solvent had no zone of inhibition, so there data was omitted from the above data. Inhibition zones including the diameter of the paper disc (6 mm). Results are expressed as the mean \pm SEM of triplicate measurements. The MIC of chloroform extract of *B. lupulina* were 6 mg/ml and 4 mg/ml against *S. aureus* and *E. coli*. 5 mg/ml and 5 mg/ml against *B. subtilis* and *P. aerogenosa*. The MIC determination was performed in triplicate for each organism. The chloroform extract exhibited (Table 4) potent anti-bacterial activity against *S. aureus* (11.12 ± 0.43 mm), *B. subtilis* (12.25 ± 0.40 mm), *E. coli* (11.33 ± 0.33 mm) and *P. aerugenosa* (13.50 ± 0.35 mm). The same for the standard drug was found to be 8 ± 0.15 mm, 9 ± 0.23 mm, 10 ± 0.22 mm and 10 ± 0.25 mm against *S. aureus*, *B. subtilis*, *E. coli* and *P. aerugenosa* respectively. The chloroform extracts of *Barleria lupulina* was produced antibacterial activity against all the tested organisms i.e. gram negative bacteria (*E. coli* and *P. aerugenosa*) and gram positive bacteria (*S. aureus* and *B. subtilis*).

In-silico Study

Binding site shows that the ligand molecule (golden yellow lines) bind with the MET1121, MET1075 and ASP1083 amino acid fragments of the 6FM4 receptor surface.

Evaluation of gel formulation

Physical characterizations

Measurement of surface pH

Spreadability



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Tube extrudability

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CONCLUSION

The findings of this study indicate that the chosen plant entity's chloroform extract has a considerable amount of antibacterial activity against four different pathogenic species. Additionally, the plant extract exhibits spectrophotometrically determined antioxidant activity, which may result in the scavenging of free radical forms inside biological systems. It has been determined that the total phenolic content may affect the antioxidant and antibacterial properties. An investigation has been conducted for a particular pathogenic bacteria enzyme whose activity may be inhibited by known phytoconstituents that have antibacterial properties. Formulations for herbal extracts have been created after careful consideration of their physicochemical properties. In the future, if the protein or enzyme structure of the pathogenic entity, responsible for the various types of diseases, is known, the herbal formulation can be tested for the antibacterial activity and further Insilico study can be done with different phytoconstituents responsible for the different activities.

REFERENCES

1. Mazumder PM, Mondal A, Sasmal D, Arulmozhi S, Rathinavelusamy P. Evaluation of antiarthritic and immunomodulatory activity of *Barleria lupulina*. Asian Pac J Trop Biomed. 2012;S1400–6.
2. Wirotasangthong M, Rattanakiat S. Anti-herpes simplex virus type 2 activities of some Thai medicinal plants. Thai j Pharm Sci. 2006; 30:19–27.
3. Sur PK. Ameliorating effect of *Barleria lupulina* Lindl. Extract against γ (gamma)-ray (1.2 Gy) induced mitotic chromosomal aberrations of house musk shrew *Suncus Murinus*. Int J of Engineering Res And Management (IJERM). 2015;2(10):2349–058.
4. Sur PK, Das PK, Das S. Effect of X-ray (120r) on the mitotic chromosomes of laboratory mice *Mus Musculus*. Proc Zool Soc India. 2012;11(1):71–82.
5. Mazumder PM, Pattnayak SP, Parvani H, Sasmal D, Paramaguru R. Evaluation of immunomodulatory activity of *Glycyrrhiza glabra* L roots in combination with zing. Asian Pac J. Trop Biomed. 2012;S15–S20.
6. Suksamrarn S, Wongkrajang K, Kirtikara K, Suksamrarn A. Iridoid glucosides from the flowers of *Barleria Lupulina*. Planta Med. 2003;69:877–9.
7. J. B. Harborne. Phytochemical Methods A GUIDE TO MODERN TECHNIQUES OF PLANT ANALYSIS Second Edition; 1984; 1-129.
8. Sarath P and Sudha Bai R. A comparative evaluation of phytochemicals in bark, leaves and seeds of *Putranjiva roxburghii* Wall. (Putranjivaceae). Journal of Pharmacognosy and Phytochemistry 2019; 8(1): 1162-1166.
9. Maurya S, Singh D, Quantitative Analysis of Total Phenolic Content in *Adhatoda vasica* Nees Extracts. Int J of Pharm Tech Res .2010; 2:2403-6.
10. Ruch R.J., Cheng S.J. & Klaunig J.E. Prevention of cytotoxicity and inhibition of intracellular communication by antioxidant catechins isolated from Chinese green tea. Carcinogenesis. 1989; 10: 1003–1008.
11. Stalons D.R., Thornsberry C. Broth-Dilution Method for Determining the Antibiotic Susceptibility of Anaerobic Bacteria. Antimicrob Agents Chemother, 7(1): 15–21, 1975.
12. Drew W.L., Barry A.L., O'Toole R., Sherris J.C. Reliability of the Kirby-Bauer disc diffusion method for detecting methicillin-resistant strains of *Staphylococcus aureus*. Appl Microbiol, 24(2): 240–247, 1972.





Anindya Bagchi et al.,

13. Tsolanku Sidney Maliehe *, Nokuthula Nomusa Mthembu and Shandu Jabulani Siyabonga. Anti-staphylococcus aureus activity, admet properties and molecular docking study of phytocompounds from *erianthemum dregei*. IJPSR, 2021; Vol. 12(6): 3349-3359.
14. Sarkar Urmistha, Raha Anusree, Mukherjee Prosenjit, Paul Monit and Bagchi Anindya. Development and Evaluation of Metronidazole Containing Topical Gel Using Different Gelling Agents. Asian Journal of Pharmacy and Pharmacology. 2018; 4(6): 785-789.

Table 1: Composition of Gel Formulation

INGREDIENTS	FORMULATION (g)
Plant extract (dry)	1
Hydroxy propyl methyl cellulose	1
Propylene glycol	2 ml
Methyl paraben	0.1
Propyl paraben	0.2
Distilled water	upto 10

Table 2: Phytochemical Screening

Plant Name	Terpenoids	Alkaloids				Glycoside	Flavonoids	Steroids	Phenolic content
		D	H	M	W				
<i>Putranjiva roxburghii</i>	-	D	H	M	W	-	+	-	+
		+	-	-	-				
<i>Ocimum tenuiflorum</i>	+	+	-	-	+	+	+	+	+

Table 3: Uv-Spectroscopic analysis of gallic acid

Conc. of gallic acid($\mu\text{g/ml}$)	Observed Absorbance
10	0.066
20	0.486
30	0.571
40	0.632
50	0.847

Table 4: Assessment of Antibacterial activity of the plant extract

Microorganisms	Diameter of inhibition zone (mm)		MIC (mg/ml)
	Chloroform extract	Streptomycin	Chloroform extract
<i>S. aureus</i>	11.12 \pm 0.43	8 \pm 0.15	6
<i>B. subtilis</i>	12.25 \pm 0.40	9 \pm 0.23	5
<i>E. coli</i>	11.33 \pm 0.33	10 \pm 0.22	4
<i>P. aeruginosa</i>	13.50 \pm 0.35	10 \pm 0.25	5

Table 5: In silico study of the phytoconstituents

Plant name	Reported isolated compound (Ligand)	Activity	Microorganisms	Protein/Receptor name	Protein/Receptor specifications
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<i>Barleria lupulina</i>	Phytol (Terpenoids)	Antibacterial	<i>S. aureus</i>	DNA gyrase	The crystal structure of <i>S. aureus</i> makes DNA Gyrase complex with ID-130 and DNA (6FM4)
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Table 6: In silico assessment

Summary of the Top 10 Models

Rank	1	2	3	4	5	6	7	8	9	10
Docking Score	-175.74	-172.78	-170.65	-169.52	-168.07	-167.37	-166.88	-164.85	-163.95	-163.89
Confidence Score	0.6259	0.6120	0.6018	0.5964	0.5894	0.5860	0.5836	0.5737	0.5693	0.5690
Ligand rmsd (Å)	54.15	52.43	53.46	53.42	54.45	69.28	54.63	68.19	67.81	55.14
Interface residues	model_1	model_2	model_3	model_4	model_5	model_6	model_7	model_8	model_9	model_10

Expected Confidence score- 0.5-0.7.

Table 7: Physical Characterizations of Gel formulation

FORMULATION	COLOUR	ODOUR	HOMOGENECITY
F1	Yellowish white	Pleasant	Homogenous

Table 8: Surface pH of Gel formulation

FORMULATION	SURFACE pH
F1	6.1

Table 9: Spreadibility of Gel formulation

FORMULATION	SPREADIBILITY (g.cm/sec)
F1	12.7

Table 10: Tube Extrudability of Gel formulation

FORMULATION	TUBE EXTRUDABILITY (g/cm ²)
F1	75

F1 =Plant extract





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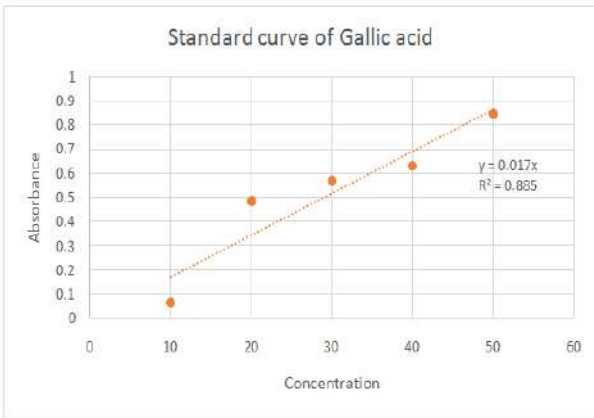


Fig 1: Standard curve of gallic acid



Fig 2: Standard drug on *S. aureus*



Fig 3: Standard drug on *P. aeruginosa*



Fig 4: Plant extract on *S. aureus*

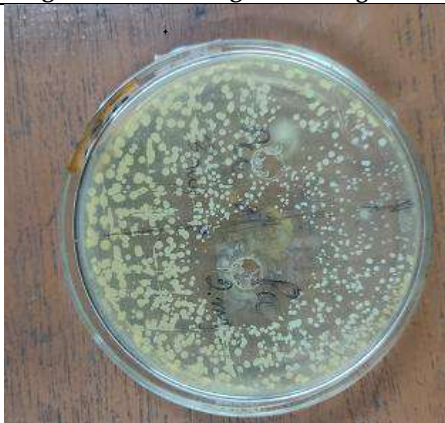


Fig 5: Plant extract on *P. aeruginosa*



Fig 6: Standard drug on *B. subtilis*





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Fig 7: Standard drug on *E. coli*

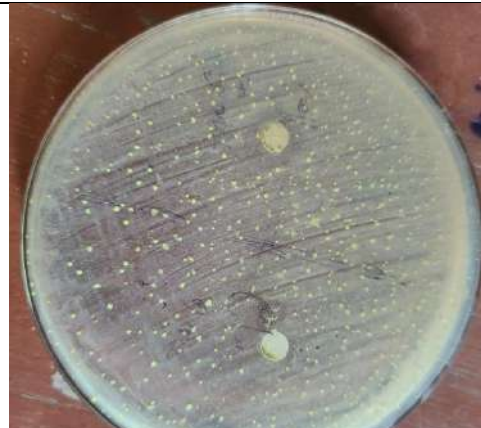


Fig 8: Plant extract on *B. subtilis*



Fig 9: Plant extract on *E. coli*



Fig 10: Protein structure of binding site data base code (6FM4)

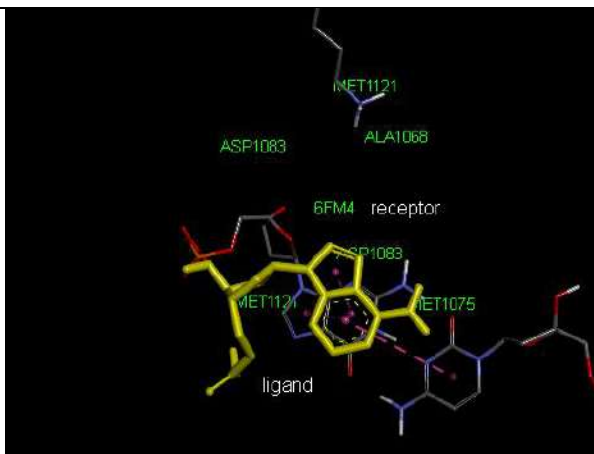


Fig 11: 3D Binding site of ligand (Phytol) in enzyme (receptor) structure

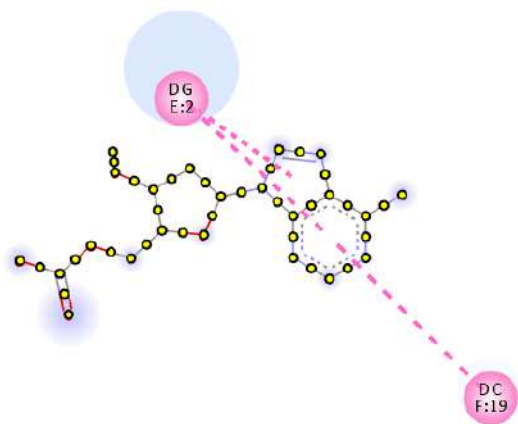


Fig 12: 2D Binding site of ligand (Phytol) in enzyme (receptor) structure





Knowledge amongst Clinicians about the Current Trends in Immediate Loading of Implants: A Questionnaire-based Survey

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ABSTRACT

Risk of early implant failure has led many clinicians to opt for a conventional approach compared to immediate. Evolution in dentistry and materials has redefined immediate loading protocols thereby aiming at a faster and enhanced treatment choice enabling improved patient satisfaction. Literature data along with improvement in the micro and macro structural components of implants has influenced many clinicians to adapt the same into their daily practice. However apart from these factors clinical outcome is dependent on clinician's judgment and surgical ability as well. The descriptive statistics included frequency rate of positive responses from ordinal data. Differences based on the years of experience and the number of implant surgery performed, the region of implant placement were evaluated using the Fisher's exact tests. With the advent of technology and research, implant dentistry strikes an appropriate balance between patient demands and immediate restoration. However, clinicians still preferred following the conventional approach due to constant fear of failure. With the appropriate techniques, thorough treatment planning and an evidence-based approach clinicians can improve the performance and surgical ability. Apart from shorter treatment period and patient satisfaction, immediate loading procedures also improve the mechanical properties and biological performance of bone.

Keywords: Immediate loading; primary stability; Implant stability quotient



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INTRODUCTION

Present trends in dentistry have evolved with increase in patient demands pertaining to superior esthetics and shorter treatment time. From introduction of osseointegration by Branemark, the protocols for implant placement have continuously been changing based on implant design, surgical technique, timing and loading of implants. The initial well-known theory of osseointegration included a healing period of 3 -4 months in the mandible and 6-8 months in the maxilla. Modern dentistry aims at shortening this healing period and introduced the concept of immediate loading. An immediate restoration has several advantages, that being reduced number of surgeries, shortened treatment course, enhancement of soft issue and patient satisfaction.¹ A Cochrane systematic review concluded no obvious difference in immediate and delayed loading of implants with respect to implant failure or bone loss². However, a successful treatment outcome for immediate loading is dependent on several factors namely, bone quality, implant design, primary stability and more importantly clinician's surgical skill.

MATERIALS AND METHODS

SAMPLE SELECTION

A questionnaire-based survey was designed for clinicians in order to assess their knowledge of immediate loading of implants, common practices, challenges faced and treatment predictability.

Interviewees

One hundred Clinicians or post graduate residents practicing Implantology were interviewed based on a set of questionnaires.

STATISTICAL ANALYSIS

The descriptive statistics included frequency rate of positive responses from ordinal data. Differences based on the years of experience and the number of implant surgery performed, the region of implant placement were evaluated using the Fisher's exact tests.

RESULTS

The data collected from the present survey were categorized based on the years of experience each respondent had to a set of questions on immediate loading and the factors essential for the same. The 3 respondents constituted of 59% of post graduate residents and the remaining 41% being clinicians with their own clinical set up. Amongst the post graduate residents 50% of them had performed 5 implant surgeries on a monthly basis and the remaining 69.7% reported around 15 and more implant placements a month. Whereas the clinicians with a n experience o 5 years 49 % of them performed only up to 5 implant rehabilitations a month and 30% them reported to have placed more than 15 implants on a monthly basis. The observed data reveals that there is no statistical significance between the years of experience of each individual and the number of implant surgeries performed in a month. Most of the respondents (87%) rarely performed immediate implant procedures. Out of the 13% of post graduate residents who performed immediate implant surgery in their practice reported most of the surgeries performed in the maxillary anterior region. However, when further asked about the common rehabilitations, 46 % of them were single tooth replacements and 53% were full arch rehabilitation. The entire population of respondents quoted radiographs to be the most important tool for pre-surgical tool for immediate implant placement. None of the respondents were keen on assessment of the stability of immediately loaded implants. When assessed for the maintenance of the immediately loaded implants, 56.6% of post graduate residents and 43.4% of the clinicians recalled the patients 6 months for evaluation. All the respondents were aware of the factors essential in the success of the treatment outcome and were quite satisfied the outcome of immediate implant restorations.



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DISCUSSION

According to Frost, Bone is a mechanostat which when externally loaded undergoes biomechanical adaptation. Adaptation to environment is natural, the same way bone does in the form of modelling and re-modelling. Remodeling occurs through resorption and formation. It is basically deposition of calcium with the help of osteoblasts, osteoclasts and TGF- β . During an implant placement, trauma and wounds created as a result of an osteotomy initiates the process of remodeling. Modelling begins at the callus and osseous margins whereas remodeling occurs at the devitalized cortical bone as a result of constant generation of functional loads. These loads are essential in the maintenance of bone physiology. Excessive loads result in modelling, whereas reduced load causes remodeling. Studies have shown that immediate loading of implants have greater bone contact and more compact bone. These findings suggest, loading of implants improved remodeling ultimately resulting in increased bone density. As proven any clinical decisions should be based on evidence, but it is eventually the clinicians who decide at the time of the surgery. Bone resorption is a normal phenomenon with implant or without. In specific hard and soft tissue changes are more pronounced in the loaded regions. Thus, assessment of clinical and radiographic parameters over the entire loading period is essential. Diagnostic tools for evaluation of the bone volume are available, however standardized technique currently used for assessment is with the help of radiographs. Our main aim in immediate loading procedures is to improve bone density. Treatment outcomes are proportional to the bone metabolism, mineralization, and vascularity[3]. Due to fear of early implant failure or poor osseointegration, clinicians prefer immediate loading in regions with good bone quality such as the mandible. The overall survival rate being excellent has led to similar application in maxilla as well. However, difference in the anatomy led to a low implant stability which resulted in lesser degree of success compared to the mandible. Despite the risk, authors have put forward various qualitative and quantitative factors to achieve a successful outcome [4].

SYSTEMIC FACTORS

Earlier systemic and local conditions were a contraindication for immediate loading. Cannizarro et al have reported successful treatment outcomes in compromised systemic conditions[5].

PRIMARY STABILITY

Primary stability being one of the factors essential for immediate loading. Stability is generally defined as 'a measure of the difficulty of displacing an object or system from equilibrium. To achieve an increased stability the implant should resist micromovement. Micro movement can be avoided with improvised techniques namely undersizing the osteotomy. This technique provides an improved torque values whilst implant placement. The other factors governing primary stability are the implant length, the diameter, design of the implant, surface modifications and surgical bed preparation. As much as this is important there are no standardized techniques recognized for the measurement of stability. Literature provides various assessment techniques for the measurement, however the most standardized currently is Periotest and devices measuring resonance frequency analysis. These devices help the clinicians in early assessment of the degree of osseointegration and implant stability. However most clinicians depend on tactile sensation for the assessment of primary stability [7]. Most practitioners in this study preferred immediate loading in the anterior region and in full mouth reconstructions. Compromised bone quality is quite common in the anterior regions. The objective of loading in these regions should yield a high Implant stability quotient (ISQ) value, and radiographic assessment. Based on prior studies failure were noted in regions of poor primary stability, less available bone height, early placement after extraction and poor hygiene.

BONE VOLUME

Another factor governing the stability is the available bone volume. An effort must be made to minimize this. One of them being atraumatic extraction to thereby minimize strains to the cortical bone. When the horizontal and vertical dimensions of the bone is unstable a staged approach is advised⁶.





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TISSUE HEALTH

Once the stability is achieved, bone volume is maintained provided tissue healing and angiogenesis is established. To maintain this, precise surgical preparation, implant torque values of 35-40 Ncm, minimal trauma to the tissues and improved prosthetic design must be ensured.

MACRO AND MICROSTRUCTURE

Clinicians rebut from loading in critical regions due to anatomical morphologies which ultimately result in poor primary stability additional to risk of soft tissue failure as well as unfavorable forces through temporary prosthesis. Regardless of these disadvantages there have been many techniques introduced over the years to combat these with improved technology and advents in implant design, surface modifications, surgical bed preparation. Implant macrostructure is an essential factor to be considered in attaining primary stability. Currently various thread geometry is available which improve the overall bone to implant contact and enhance osseointegration. Thread designs improve the surface area for bone contact and by load transmission with the help of improving compressive stresses. Thread designs currently available are square, V, buttress, reverse buttress etc. Other factors to be considered for improving stability employed the use of osteophilic surfaces to bear early implant loading[8 9 10]. The protocol for any single implant placement is proper alignment, level of the adjacent bone and reduced occlusal contact. Basically, no excursive contacts and no occlusal loading in a provisional restoration. Whilst planning full arch reconstructions the critical element is distribution of forces evenly. For patients with full arch immediate loading minimizing occlusal contact is unavoidable. Poor occlusal loading result in micro strain. Factor to be considered are primarily the number of implants with minimized cantilever forces^{11 12}.

CONCLUSION

Surgical skill and approach compensate for the variations in anatomies of the jaw and individual patient factors. Primary stability is an ultimate in immediate loading. Identifying factors essential for improving the stability and techniques to consider for its assessment determines the course of the treatment. Success varies within individuals. An evidence-based approach must be followed to evaluate the various possibilities.

REFERENCES

1. Misch CE. Contemporary implant dentistry. *Implant Dentistry*. 1999 Jan 1;8(1):90.
2. Tettamanti, L., Andrisani, C., Bassi, M. A., Vinci, R., Silvestre-Rangil, J., & Tagliabue, A. (2017). Immediate loading implants: review of the critical aspects. *ORAL & implantology*, 10(2), 129–139.
3. Esposito M, Grusovin MG, Maghaireh H, Worthington HV. Interventions for replacing missing teeth: different times for loading dental implants. *Cochrane Database Syst Rev*. 2013 Mar 28;2013(3)
4. Szmukler-Moncler S, Piattelli A, Favero GA, Dubruille JH. Considerations preliminary to the application of early and immediate loading protocols in dental implantology. *Clinical oral implants research*. 2000 Feb;11(1):12-25.
5. Cannizzaro G, Leone M. Restoration of partially edentulous patients using dental implants with a microtextured surface: a prospective comparison of delayed and immediate full occlusal loading. *International Journal of Oral & Maxillofacial Implants*. 2003 Jul 1;18(4).
6. Bahat O. Treatment planning and placement of implants in the posterior maxillae: report of 732 consecutive Nobelpharma implants. *International Journal of Oral & Maxillofacial Implants*. 1993 Mar 1;8(2).
7. Yoon HG, Heo SJ, Koak JY, Kim SK, Lee SY. Effect of bone quality and implant surgical technique on implant stability quotient (ISQ) value. *The journal of advanced prosthodontics*. 2011 Mar;3(1):10.
8. Hoshaw SJ, Brunski JB, Cochran GV. Mechanical loading of Brånemark implants affects interfacial bone modeling and remodeling. *International Journal of Oral & Maxillofacial Implants*. 1994 May 1;9(3).





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9. Abuhussein H, Pagni G, Rebaudi A, Wang HL. The effect of thread pattern upon implant osseointegration. Clinical oral implants research. 2010 Feb;21(2):129-36.
10. Chaushu G, Chaushu S, Tzohar A, Dayan D. Immediate loading of single-tooth implants: immediate versus non-immediate implantation. A clinical report. International Journal of Oral & Maxillofacial Implants. 2001 Mar 1;16(2).
11. Östman PO, Hellman M, Sennerby L. Direct implant loading in the edentulous maxilla using a bone density-adapted surgical protocol and primary implant stability criteria for inclusion. Clinical implant dentistry and related research. 2005 Jun;7:s60-9.
12. Chiapasco M. Early and immediate restoration and loading of implants in completely edentulous patients. International Journal of Oral & Maxillofacial Implants. 2004 Nov 2;19(7).

Table 1: Years of experience * Number of implant surgeries performed on a monthly basis.

Crosstab					
			Number of implant surgeries performed on a monthly basis		Total
			A	D	
Years of experience	PG	Count	34	23	57
		% Within Years of experience	59.6%	40.4%	100.0%
		% Within Number of implant surgeries performed on a monthly basis	50.7%	69.7%	57.0%
	0-5	Count	33	10	43
		% Within Years of experience	76.7%	23.3%	100.0%
		% Within Number of implant surgeries performed on a monthly basis	49.3%	30.3%	43.0%
Total	Count	67	33	100	
	% Within Years of experience	67.0%	33.0%	100.0%	
	% Within Number of implant surgeries performed on a monthly basis	100.0%	100.0%	100.0%	

Chi-Square Tests					
	Value	Df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	3.240 ^a	1	.072		
Continuity Correction ^b	2.513	1	.113		
Likelihood Ratio	3.311	1	.069		
Fisher's Exact Test				.088	.056
Linear-by-Linear Association	3.207	1	.073		
N of Valid Cases	100				
a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 14.19.					
b. Computed only for a 2x2 table					





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Table 2: Years of experience * Have you performed immediate loading?

Crosstab					
			Have you performed immediate loading?		Total
			A	B	
Years of experience	PG	Count	13	44	57
		% Within Years of experience	22.8%	77.2%	100.0%
		% Within Have you performed immediate loading?	100.0%	50.6%	57.0%
	0-5	Count	0	43	43
		% Within Years of experience	0.0%	100.0%	100.0%
		% Within Have you performed immediate loading?	0.0%	49.4%	43.0%
Total	Count		13	87	100
	% Within Years of experience		13.0%	87.0%	100.0%
	% Within Have you performed immediate loading?		100.0%	100.0%	100.0%

Table 3: Years of experience * How often do you immediately load your implants?

Crosstab					
			How often do you immediately load your implants?		Total
			B	C	
Years of experience	PG	Count	13	44	57
		% Within Years of experience	22.8%	77.2%	100.0%
		% Within How often do you immediately load your implants?	100.0%	50.6%	57.0%
	0-5	Count	0	43	43
		% Within Years of experience	0.0%	100.0%	100.0%
		% Within How often do you immediately load your implants?	0.0%	49.4%	43.0%
Total	Count		13	87	100
	% Within Years of experience		13.0%	87.0%	100.0%
	% Within How often do you immediately load your implants?		100.0%	100.0%	100.0%

Table 4: Years of experience * Which region have you most often done immediate loading on?

Crosstab				
			Which region have you most often done immediate loading on?	Total
			A	
Years of experience	PG	Count	15	15
		% Within Years of experience	100.0%	100.0%
		% Within Which region have you most often done immediate loading on?	100.0%	100.0%
Total	Count		15	15
	% Within Years of experience		100.0%	100.0%





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	% Within Which region have you most often done immediate loading on?	100.0%	100.0%
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Table 5: Years of experience * Commonly performed immediate loading surgeries.

Crosstab					
		Commonly performed immediate loading surgeries		Total	
		A	C		
Years of experience	PG	Count	7	8	15
		% Within Years of experience	46.7%	53.3%	100.0%
		% Within Commonly performed immediate loading surgeries	100.0%	100.0%	100.0%
Total		Count	7	8	15
		% Within Years of experience	46.7%	53.3%	100.0%
		% Within Commonly performed immediate loading surgeries	100.0%	100.0%	100.0%

Table 6: Years of experience * Most common tool for pre-surgical evaluation

Crosstab				
		Most common tool for pre-surgical evaluation		Total
		C		
Years of experience	PG	Count	57	57
		% Within Years of experience	100.0%	100.0%
		% Within Most common tool for pre-surgical evaluation	57.0%	57.0%
	0-5	Count	43	43
		% Within Years of experience	100.0%	100.0%
		% Within Most common tool for pre-surgical evaluation	43.0%	43.0%
Total		Count	100	100
		% Within Years of experience	100.0%	100.0%
		% Within Most common tool for pre-surgical evaluation	100.0%	100.0%

Table 7: Years of experience * Do You assess for stability of an immediately loaded implant?

Crosstab				
		Do You assess for stability of an immediately loaded implant?		Total
		B		
Years of experience	PG	Count	57	57
		% Within Years of experience	100.0%	100.0%
		% Within Do You assess for stability of an immediately loaded implant?	57.0%	57.0%





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	0-5	Count	43	43
		% Within Years of experience	100.0%	100.0%
		% Within Do You assess for stability of an immediately loaded implant?	43.0%	43.0%
Total		Count	100	100
		% Within Years of experience	100.0%	100.0%
		% Within Do You assess for stability of an immediately loaded implant?	100.0%	100.0%

Table 8: Years of experience * According to you the success of the treatment is dependent on

Crosstab				
		According to you the success of the treatment is dependent on		Total
		E		
Years of experience	PG	Count	57	57
		% Within Years of experience	100.0%	100.0%
		% Within According to you the success of the treatment is dependent on	57.0%	57.0%
	0-5	Count	43	43
		% Within Years of experience	100.0%	100.0%
		% Within According to you the success of the treatment is dependent on	43.0%	43.0%
Total		Count	100	100
		% Within Years of experience	100.0%	100.0%
		% Within According to you the success of the treatment is dependent on	100.0%	100.0%





Ethnomedicinal Plants in India: A Comprehensive Review of their Therapeutic Potential and Phytochemical Constituents

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ABSTRACT

Herbal plants have been an integral part of traditional medicine systems across the globe for centuries. This comprehensive review unveils the remarkable therapeutic potential of various ethnomedicinal plants by critically analyzing scientific studies on their phytochemical constituents and pharmacological activities. Extensive research has demonstrated the antioxidant properties of plants like *Alangium salviifolium*, *Balanites aegyptiaca*, and *Ficus racemosa*. Their antimicrobial efficacy against a wide range of pathogens, including antibiotic-resistant strains, has also been established. Notably, several plants exhibited promising anticancer effects, inducing apoptosis and cell cycle arrest in various cancer cell lines. Furthermore, this review highlights the anti-diabetic potential of plants such as *Cadabafruticosa* and *Diplocyclospalmatus*, which can regulate postprandial hyperglycemia and inhibit key enzymes involved in carbohydrate metabolism. Plants like *Azimatetracantha* and *Lawsoniainermis* displayed remarkable analgesic, anti-inflammatory, and wound-healing properties. This comprehensive analysis not only validates the traditional use of these plants but also opens avenues for future research in drug discovery and development. The findings underscore the urgent need for conservation and sustainable utilization of these valuable natural resources.

Keywords: Ethnomedicinal plants, Phytochemicals, Antioxidants, Anticancer, Anti-diabetic, Medicinal properties





INTRODUCTION

Ethnobotany explores how indigenous communities interact with their natural surroundings, involving plant categorization, cultivation, and use. Medicinal plants have played a historic role in healthcare, leading to plant-derived pharmaceuticals worldwide (1). Traditional medicine encompasses diverse practices, incorporating plant, animal, mineral remedies, spiritual therapies, and exercises for wellness. Defining traditional medicine globally is challenging due to its wide scope and varied practices. Typically, it's considered "traditional" when practiced within its country of origin (2). Indigenous knowledge, shaped by human-environment interaction, exists globally. Each region has its unique approach to health, diseases, and therapies, with traditional healers and plant-based remedies playing vital roles. Ethnobotanical studies are essential for documenting the intricate link between plant diversity and human societies, revealing how human activities impact nature and culture(1–3). Local wisdom, even in developed nations, supports resource use practices in pastoral, farming, and wild resource gathering communities. Indigenous knowledge guides decisions and actions, with around 80% of the world's population relying on traditional remedies for primary healthcare (4). The utilization of plants in disease management dates back to ancient times and has consistently been regarded as a valuable resource for the development of new drugs to address various disorders (5–7). Globally, 21.1% of people in high-income countries and 26.4% in a broader study used traditional and complementary medicine (TCM) providers in the past year. Factors affecting TCM use include sociodemographic and health-related factors. In India, TCM, particularly AYUSH systems, are more commonly used by economically disadvantaged groups, specific geographical regions, tribal populations, and those with chronic illnesses or specific health conditions like skin and musculoskeletal problems(8). Extensive research has been conducted on natural plant substances, and it is therefore necessary to provide a comprehensive review of recent advances in this field. This review will cover the types of natural plant substances found traditionally in India, their national geographical distribution and various researches focusing on the recent ones on specific plants. Hopefully this timely review will provide valuable insights for future research on this plant substances.

METHODOLOGY

The literature search used scientific databases like PubMed, Scopus, and Google Scholar to collect all relevant articles published in English until 2023. The goal was to explore various plants and their pharmacological activities. Scientific names and synonyms were verified using Plants of the World Online and World Flora Online. Plant images were obtained via Google search and these websites. Additionally, indigenous knowledge was gathered through oral interviews with experts in traditional medicine, including villagers, vadiyas, hakims, herbalists, and tribal communities, using structured questionnaires.

Geographical Distribution of Herbal Plants

The plants mentioned in this review have a wide distribution all over the world and in particular in India. Due to multiple medicinal plants found at various locations in India a single simpler map is designed to show the context of plant availability in nature as many of them are found in similar locations throughout India (**Figure i**): **Green Dots in the figure represents:** *Alangium salvifolium*, *Aristolochia indica*, *Azimatetracantha*, *Balanites aegyptiaca*, *Butea monosperma*, *CadabaFruticosa*, *Capparis Zeylanica*, *Corollocarpusepigaeus*, *Diplocyclospalmatus*, *Elytraria acaulis*, *Ficus racemose*, *Grewia hirsute*, and *Law soniainermis*.

Ethanobotanical survey and traditional uses of medicinal plants

Individual Herbs

1. *Alangium salviifolium*

Alangium salviifolium (L. f.) Wang, also known as *A. lamarckii* Thwaites, is a deciduous shrub belonging to the Alangiaceae family. It has a rich tradition of being used for medicinal purposes in different regions, with a particular focus on India, China, and the Philippines (9). Some synonyms for *A. salviifolium* include *A. decapetalum* Lam, *A. lamarckii* Thw, and it is a tall, thorn-bearing tree, and the genus comprises 17 species, including small trees,



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shrubs, and climbing plants(10). In the context of Ayurveda, both the roots and fruits play a crucial role in addressing various conditions such as rheumatism, burning sensations, and hemorrhages. For instance, in the Philippines the bark of *A. salvifolium* was traditionally employed as an external remedy for counteracting the effects of snake and scorpion bites (11) while in the Comoros, the whole plant also served as a decoction and when it was used alongside with coconut, it helped to treat boils. Other countries like China also reported that the plant cures asthma (12). Ankol seeds possess antimicrobial, diuretic, anti-cancer, and anti-diabetic attributes while the stem exhibits properties that make it effective against diarrhea and nausea(13,14) and methanol was also found in flower extract which showed an effect on free radical scavenging (15).

2. *Aristolochia indica*

Aristolochia indica L (AI) belongs to the family Aristolochiaceae and according to ayurveda it is used for fever, snake venom, worm infection, and pimple (16,17). This particular species is found across India, Bangladesh, Sri Lanka, and Nepal, and it can be observed in both the plains and hilly regions of India in particular (18) Aristolic acid, extracted from the chloroform extract, demonstrates complete abortifacient activity as it effectively prevented estrogen-induced (EI) weight gain, inhibited uterine epithelial growth (UEG), and hindered implantation during the early stages of pregnancy (19). Methanolic extracts testing was done against Daboia russellisnake venom, and the results showed a complete neutralization of the venom's deadly effects and neutralization of edema, hemorrhage, fibrinolysis, and phospholipase (PL) activities (20). Naik et al., assessed the antibacterial and antifungal properties of AI leaves and flowers using the agar well diffusion method for bacteria and the poisoned food technique for fungi. The leaf extract showed notable antibacterial activity, while the flower extract demonstrated significant antifungal activity (21)

3. *Azimatetracantha*

Azimatetracantha is a traditional medicinal plant that belongs to the order Brassicales and the family Salvadoraceae(22). In Tamil, *Azimatetracantha* is referred to as Mulsangu, and in Sanskrit, it is known as Kundali(23). *Azimatetracantha* is found distributed across various regions, including India, tropical Africa, Madagascar, the Philippines, and Sri Lanka. In India, you can find this plant in states such as Karnataka, Kerala, Maharashtra, Tamil Nadu, Orissa, and West Bengal (24). Compounds extracted from the leaves of *A. tetracantha*, specifically alkaloids, flavonoids, and sterols, and were found to possess inhibitory activity against a range of both Gram-positive and Gram-negative bacteria (24) and Natarajan et al. showed the capability of the extract to inhibit reference strains of both bacteria and fungi, as well as clinical isolates of bacteria and fungi obtained from diabetic foot infections (25). Sridharan et al., investigated the antiarthritic activity of the ethanolic extract derived from the entire plant using the Freund's complete adjuvant (FCA)-induced arthritis method. The extract exhibited antiarthritic activity (26)and analgesic activity was reported using the hot plate method with mice as test subjects and this was comparable to the effects of the standard drug Pentazocine (27).

4. *Balanites aegyptiaca*

Balanites aegyptiaca Del., commonly referred to as the 'Desert date' belonging to the Zygophyllaceae family and is indigenous to various regions in Africa and some areas within the Middle East. In India, it is prominently distributed in the states of Rajasthan, Gujarat, and Madhya Pradesh (28). It is also known by the alternate names of Ingudi, Hingam, Balsam, and Hingan. *B. aegyptiaca* is utilization in both African and Indian traditional medicinal practices(29). The unrefined aqueous extract obtained from the root bark of *B. aegyptiaca* demonstrated a dosage-dependent suppression of motility in adult earthworms and exhibited vermucidal properties (30). While, the ethanolic extract from the fruits also showed anthelmintic effects against various developmental stages of *Trichinella spiralis* in rats, outperforming albendazole (31). Balanitin 1 and balanitin 2 are saponins isolated from bark extracts, having antioxidant properties in vitro (32) and the primary components responsible for these antioxidant activities are polyphenols, specifically quercetin and kaempferol (33). This extracts from exerted protection to hepatocytes in rats against hepatotoxicity induced by paracetamol and CCl₄ (34). A blend of steroidal saponins exhibited significant anti-cancer effects when tested on human cancer cell lines in a laboratory setting and extended the survival time of



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mice with murine L1210 leukemia grafts by an equivalent degree as reported for vincristine (35,36).

5. *Butea monosperma*

Butea monosperma (Lam.) Taub, also recognized as *Butea frondosa* and belonging to the Fabaceae family, is commonly referred to by various names including 'dhak' or 'palas.' It is popularly known as the 'Flame of the Forest' and also goes by names such as palash, mutthuga, bijasneha, khakara, chichara, Bastard teak, and Bengal kino (37). This tree species has a wide distribution range encompassing India, Burma, and Ceylon (38). Parween et al., explored the impact of methanolic extract on the fertility of male albino rats and a noteworthy 40% decrease in fertility rates and a decrease in both testicular and epididymal weights, suggesting the flowers antifertility properties (38). Sharma et al., explored the antibacterial and antidiarrheal properties against a newly isolated gram-negative pathogenic bacterial strain known as *Enterobacter cloacae*. The findings indicated that *B. monosperma* bark could be employed effectively to combat waterborne diseases (39) and Kaur et al., suggested that the bark extracts demonstrated promising anti-proliferative effects on MCF-7 cells, inducing apoptosis, altering cell cycle phases, increasing ROS levels, disrupting mitochondrial membrane potential, and causing double-strand DNA breaks (40).

6. *CadabaFruticosa*

The plant *Cadabafruticosa*, a member of the Caparaceae family, can be located worldwide (41), including regions such as Gujarat and Karnataka in India (42). It exhibits promising qualities as an anti-diarrheal, anti-syphilis, anti-gonorrhoeal agent, and rejuvenator (43). Additionally, its leaves are known to possess anti-diabetic and antipyretic properties (42,44). A study attempted to retard the absorption of glucose using the ethanolic leaf extract of *C. fruticosa* and this approach intended to help regulate postprandial hyperglycemia(35). Furthermore, Arokiyaraj, S. et al identified alcoholic extracts like flavonoids, terpenoids, and steroids, as valuable substances in the formulation of phytomedicines for diabetes treatment (42). Lavinya, B. et al., also found that methanolic leaf extract exhibited notable antimicrobial and antioxidant properties due to the phenolic content, and ability to scavenge free radicals(45)suggesting their potential as valuable therapeutic agents for mitigating pathological damage associated with free radicals(46). The plant is found to contain significant levels of hydroxyurea, an antineoplastic drug known to decrease the frequency of painful episodes in sickle-cell disease and exhibit antiretroviral effects in conditions like HIV/AIDS. Several imidazole derivatives are identified suggesting the potential antifungal activity (47).

7. *Capparis Zeylanica*

Capparis zeylanica is a sturdy, bushy shrub with extensive distribution across India, Sri Lanka, Bangladesh and Malaysia. It is referred to as the Indian caper and belongs to the Capparidaceae family (48,49). It contains a variety of active compounds that contribute to its various biological effects, including antioxidant, antidiabetic, antitumoral, immunostimulant, antibacterial and antiscerotic properties (50). Tripathi, A. et al., studied *C. zeylanica* extract and it showed strong antiulcer properties against chemically-induced ulcers, coupled with notable antimicrobial activity. The extract demonstrated effectiveness in treating both acute and chronic ulcers by reducing ulcer size and restored the normal stomach morphology in ulcerated cases (49). Solanki, R. et al., studied the potential of methanolic and aqueous extracts from leaves in rats, and it showed a strong nootropic and the antioxidant characteristics playing a beneficial role in enhancing memory (51). Furthermore, noteworthy wound healing properties in both excision and incision wound models were also identified (52).

8. *Lawsoniainermis*

Henna, scientifically known as *Lawsoniainermis* L., is a fragrant tree or shrub often utilized in the cosmetics industry. In Morocco, it goes by the name Henné, while in Sanskrit, it is referred to as Mendhi, Mendika, Timir, and several other names. Pharmacological investigations have revealed that *Lawsoniainermis* L. possesses a range of properties, including antifungal, antibacterial, antitumor, and many others (53). Traditional Persian medicine recommends henna oil for sciatica pain relief. A study by Lavari, N. et al. investigated its efficacy in chronic sciatica patients, finding it effectively reduces pain, enhances quality of life, and improves functionality although more randomized controlled trials are needed (54). Furthermore, it was indicated exhibits notable analgesic effects when compared to



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standard drug (diclofenac) in wistar rats using writhing and paw lick responses (55). The seed components, especially the aqueous extracts from their cotyledons and coats of the plant, displayed potent antibacterial activity against antibiotic-resistant strains of *S. aureus* and *P. aeruginosa* (55).

CONCLUSION

This review examined various herbal plants traditionally used for medicinal purposes worldwide. These plants showed diverse activities such as antioxidant, antimicrobial, anticancer, anti-diabetic, analgesic, and hepatoprotective effects. Evidence supports their therapeutic efficacy, but more research is needed to understand their mechanisms, identify active compounds, and confirm safety and efficacy through clinical trials. Traditional knowledge and ethnobotanical uses provide a valuable starting point for scientific investigations and potential natural therapies. Preserving plant resources and traditional knowledge is crucial, ensuring sustainable use and protecting indigenous communities' intellectual property rights. In summary, herbal plants have immense potential as sources of bioactive compounds for diverse therapeutic applications. Combining traditional wisdom with modern science can develop safe, effective, and accessible therapies to improve human health.

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REFERENCES

1. Martin GJ. Ethnobotany: a methods manual. Routledge; 2010.
2. Balick MJ, Cox A. Plants that heal; people and culture: the science of ethno botany. 1996;
3. Cotton CM. Ethnobotany: principles and applications. John Wiley & Sons; 1996.
4. Nakashima D, Roué M. Indigenous knowledge, peoples and sustainable practice. Encyclopedia of global environmental change. 2002;5:314–24.
5. Karami S, Shamshiri S, Abdollahi M, Rahimi R. An evidence-based review of medicinal plants used in traditional Persian medicine for treatment of osteoarthritis. *Curr Drug Discov Technol.* 2021;18(2):244–71.
6. Mehraban MSA, Tabatabaei-Malazy O, Rahimi R, Daniali M, Khashayar P, Larijani B. Targeting dyslipidemia by herbal medicines: A systematic review of meta-analyses. *J Ethnopharmacol.* 2021;280:114407.
7. Bahramsoltani R, Rahimi R. An evaluation of traditional Persian medicine for the management of SARS-CoV-2. *Front Pharmacol.* 2020;11:571434.
8. Pengpid S, Peltzer K. Utilization of complementary and traditional medicine practitioners among middle-aged and older adults in India: results of a national survey in 2017–2018. *BMC Complement Med Ther.* 2021;21:1–11.
9. Ratra M, Gupta R. Comprehensive review on pharmacological profile of *Alangiumsalvifolium*: A medicinal plant. *Pharmaceutical and Biosciences Journal.* 2015;22–8.
10. Panara K, Singh PK, Rawat P, Kumar V, Maruf M, Patel K, et al. Importance of *Alangiumsalviifolium* and its pharmacological update. *European J Med Plants.* 2016;12(4):1–15.
11. Rajamanickam V, Rajasekaran A, Quine S, Jesupillai M, Sabitha R. Diuretic activity of *Alangiumsalvifolium* sub. sp. *hexapetalum*. *Int J Alt Med.* 2009;8(1).
12. Jana GK, Gupta A, Das A, Tripathy R, Sahoo P. Herbal Treatment To Skin Diseases: A Global Approach. *Drug Invention Today.* 2010;2(8).
13. Ronok Z, Anamul H, Laizumari N, Ashik M, Ekramul H. Evaluation of anxiolytic and CNS depressant activity of *Alangiumsalviifolium* wang flowers. *International Research Journal of Pharmacy.* 2012;3(4):2230–8407.





Parmar et al.,

14. Raghavendra P, Prasad AGD, Shyma TB. Investigations on anti-diabetic medicinal plants used by tribes of Wayanad district, Kerala. 2015;
15. Bhosale AS, Singh G. Antioxidant potential of different solvent extracts isolated from *Alangiumsalvifolium* flowers. *European Journal of Molecular & Clinical Medicine*. 2020;7(09):2020.
16. Reddy MB, Reddy KR, Reddy MN. A survey of medicinal plants of Chenchu tribes of Andhra Pradesh, India. *Int J Crude Drug Res*. 1988;26(4):189–96.
17. Mansoor NR, Sanmugarajah V. A literature review on medicinal plants that are being used in traditional medicine for the management of the snake bites in Sri Lanka. *Asian Plant Research Journal*. 2018;1(1):1–18.
18. Padhy GK. A review of *Aristolochia indica*: Ethnomedicinal uses, phytochemistry, pharmacological and toxicological effects. *Current Traditional Medicine*. 2021;7(3):372–86.
19. Pakrashi A, Chakrabarty B. Anti-oestrogenic and anti-implantation effect of aristolic acid from *Aristolochia indica* (Linn.). 1978;
20. Meenatchisundaram S, Parameswari G, Michael A. Studies on antivenom activity of *Andrographis paniculata* and *Aristolochia indica* plant extracts against *Daboia russelli* venom by in vivo and in vitro methods. *Indian J Sci Technol*. 2009;76–9.
21. Abhishiktha SN, Saba S, Shrunga MN, Sunitha KL, Prashith KTR, Raghavendra HL. Antimicrobial and Radical Scavenging Efficacy of Leaf and Flower of *Aristolochia indica* Linn. *Science, Technology and Arts Research Journal*. 2015;4(1):103–8.
22. Malayil D, Jose B, Narayanankutty A, Ramesh V, Rajagopal R, Alfarhan A. Phytochemical profiling of *Azimatetracantha* Lam. leaf methanol extract and elucidation of its potential as a chain-breaking antioxidant, anti-inflammatory and anti-proliferative agent. *Saudi J Biol Sci*. 2021;28(11):6040–4.
23. Sunil C, Duraipandiyam V, Ignacimuthu S, Al-Dhabi NA. Antioxidant, free radical scavenging and liver protective effects of friedelin isolated from *Azimatetracantha* Lam. leaves. *Food Chem*. 2013;139(1–4):860–5.
24. Gowthami M, Selvi ST. Phytochemical analysis and antibacterial properties of leaf extract of *Azimatetracantha* (Lam.). *Asian Journal of Plant Science & Research*. 2011;
25. Natarajan K, Rashid T, Shuhaib CK, Balu V. *Azimatetracantha* Lam. against causative agents in diabetic foot infections. *Innovare J Health Sci*. 2014;2:9–12.
26. Sridharan C, Jose AM, Radhakrishnan R, Manisenthilkumar KT. Anti-inflammatory and anti-arthritic activity of *Azimatetracantha* (LAM) whole plant in albino wistar rats. In: *INDIAN JOURNAL OF PHARMACOLOGY. MEDKNOW PUBLICATIONS A-108-109 KANARA BUSINESS CENTRE, GHAKTOPAR, MUMBAI ...*; 2008. p. 83.
27. Begum TN, Anand AV. Analgesic activity of *Azimatetracantha* in experimental animals. *Research Journal of Pharmacology and Pharmacodynamics*. 2010;2(6):384–7.
28. Chothani DL, Vaghasiya HU. A review on *Balanites aegyptiaca* Del (desert date): phytochemical constituents, traditional uses, and pharmacological activity. *Pharmacogn Rev*. 2011;5(9):55.
29. Orwa C. Agroforestry Database: a tree reference and selection guide, version 4.0. <http://www.worldagroforestry.org/sites/treedbs/treedatabases.asp>. 2009;
30. Dwivedi A, Joshi V, Barpete PK, Akhtar AK, Kaur A, Kumar S. Anthelmintic Activity of Root Bark of *Balanites aegyptiaca* (L.) Del. *Ethnobotanical Leaflets*. 2009;2009(5):1.
31. Shalaby MA, Moghazy FM, Shalaby HA, Nasr SM. Effect of methanolic extract of *Balanites aegyptiaca* fruits on enteral and parenteral stages of *Trichinella spiralis* in rats. *Parasitol Res*. 2010;107:17–25.
32. Speroni E, Cervellati R, Innocenti G, Costa S, Guerra MC, Dall'Acqua S, et al. Anti-inflammatory, anti-nociceptive and antioxidant activities of *Balanites aegyptiaca* (L.) Delile. *J Ethnopharmacol*. 2005;98(1–2):117–25.
33. Rasouli H, Farzaei MH, Khodarahmi R. Polyphenols and their benefits: A review. *Int J Food Prop*. 2017;20(sup2):1700–41.
34. KL M, .V K, Krishnaswamy M, sm V, SD J, Manohara YN, et al. Evaluation of hepatoprotective activity of stem bark of *Pterocarpus marsupium* Roxb. *Indian Journal of Pharmacology* (ISSN: 0253-7613) Vol 37 Num 3. 2005 Jun 1;37.





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35. T E, Surendran H, S S, R M, Hari R. Invitro and insilico anti hyperglycemic activity of cadabafruticosa leaves - an enteric approach. International Journal of Research in Pharmaceutical Sciences. 2019 Oct 16;10:2837–44.
36. Pettit GR, Doubek DL, Herald DL, Numata A, Takahasi C, Fujiki R, et al. Isolation and Structure of Cytostatic Steroidal Saponins from the African Medicinal Plant *Balanites aegyptica*. J Nat Prod [Internet]. 1991 Nov 1;54(6):1491–502. Available from: <https://doi.org/10.1021/np50078a002>
37. Sindhia VR, Bairwa R. Plant review: *Butea monosperma*. International journal of pharmaceutical and clinical research. 2010;2(2):90–4.
38. Chopra RN, Chopra IC. Handa. K. L., and Kapur, LD, "Indigenous Drugs of India," 2nd Ed., VN Dhur and Sons, Calcutta, India. 1958;
39. Farooq MU, Mumtaz MW, Mukhtar H, Rashid U, Akhtar MT, Raza SA, et al. UHPLC-QTOF-MS/MS based phytochemical characterization and anti-hyperglycemic prospective of hydro-ethanolic leaf extract of *Butea monosperma*. Sci Rep. 2020;10(1):3530.
40. Sharma D, Patel S, Verma K, Gudlawar S, Chakraborty D, Paliwal S, et al. Antibacterial and antidiarrheal activity of *Butea Monospermea* bark extract against waterborne enterobacter Cloacae in rodents: In-vitro, Ex-vivo and In-Vivo evidences. J Ethnopharmacol. 2019;241:112014.
41. Kaur V, Kumar M, Kumar A, Kaur S. *Butea monosperma* (Lam.) Taub. Bark fractions protect against free radicals and induce apoptosis in MCF-7 breast cancer cells via cell-cycle arrest and ROS-mediated pathway. Drug Chem Toxicol. 2020;43(4):398–408.
42. Arokiyaraj S, Radha R, Martin S, Perinbam K. Phytochemical analysis and anti-diabetic activity of *Cadabafruticosa* R. Br. Indian J Sci Technol. 2008;1–4.
43. Gayake DN, Sharma PP. Vijigiri Dinesh, 2012. Plants used in medicine by folklore of Ahmednagar district, Maharashtra. International J of Sci and Pharma Educational Res. 1(3):19–24.
44. Mythreyi R, Sasikala E, Geetha A, Madhavan V. Antipyretic activity of leaves of *Cadabafruticosa* (L.) Druce. Pharmacol Online. 2008;3:136–42.
45. Lavinya BU, Akalya JL, Srujana KSL, Sabina EP, Rajeswari VD. Appraisal of the in vitro antibacterial and anti-oxidant potential of the leaf extracts of *Cadabafruticosa*. Asian J Pharm Clin Res. 2014;7:118–20.
46. Amudha M, Rani S. STUDY OF ANTIOXIDANT POTENTIAL OF CADABA FRUTICOSA BY USING VARIOUS IN VITRO MODELS. 2014;
47. Saha H, Srikanth A, Sikchi S, Rajeswari VD. Comparative evaluation of antimicrobial and anti-inflammatory activities of *Ocimum sanctum*, *Phyllanthus niruri* and *Cadabafruticosa*: an in vitro approach with emphasis on detection of their bioactive compounds using GC-MS. International Journal of Biological Chemistry. 2015;9(5):235–48.
48. Ghule B V, Muruganathan G, Yeole PG. Analgesic and antipyretic effects of *Capparis zeylanica* leaves. Fitoterapia. 2007;78(5):365–9.
49. Tripathi A, Singh S, Mukerjee A. Antiulcer activity of ethanolic leaf extract of *Capparis zeylanica* against chemically induced ulcers. Futur J Pharm Sci. 2021;7:1–13.
50. Tlili N, Elfalleh W, Saadaoui E, Khaldi A, Triki S, Nasri N. The caper (*Capparis* L.): Ethnopharmacology, phytochemical and pharmacological properties. Fitoterapia. 2011;82(2):93–101.
51. Solanki R, Chaudhary AK, Singh R. Effect of leaf extract of *Capparis zeylanica* Linn. on spatial learning and memory in rats. J Nat Med. 2012;66:600–7.
52. Chandan Das C Das, Sujit Dash SD, Sahoo DC, Sahu AK, RaghunandanHota RH, Dolley Rout DR. Wound healing activity of *Capparis zeylanica* (root). 2011;
53. Moutawalli A, Benkhouili FZ, Doukkali A, Benzeid H, Zahidi A. The biological and Pharmacologic Actions of *Lawsoniainermis* L. Phytomedicine Plus. 2023;100468.
54. Lavari N, Ostadrahimi N, Rahimi R, Raei M, Abbassian A. The effect of a topical formulation from *Lawsoniainermis* L.(henna) on pain intensity in patients with chronic sciatica: A randomized double-blind clinical trial. J Ethnopharmacol. 2023;313:116519.
55. Aremu A, Idris JF, Akorede GJ, Olatumji AO, Basiru A, Ahmed AO. *Lawsoniainermis* possesses a significant analgesic activity compared to *Waltheria indica*, *Moringa oleifera*, *Nigella sativa*, and diclofenac in female Wistar rats. Iran J Vet Sci Technol. 2023;15(2):48–55.





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Table 1: Ethanobotanical survey and traditional uses of medicinal plants

Activity/Action	Herbal Plants	Location	Research Findings
Antioxidant	<i>Alangiumsalviifolium</i> (Fruits), <i>Balanites aegyptiaca</i> (Bark extracts), <i>Ficus racemosa</i> (Leaf extracts), <i>Grewia hirsuta</i> (Leaf extracts)	India, China, Philippines, Africa, Middle East, India, Africa, Asia, Australia, Bangladesh, Cambodia, China, India and warmer regions	Fruits possess anxiolytic, CNS depressant, and anti-diabetic activity. Bark extracts have antioxidant properties. Leaf extracts showed radical scavenging activity. Leaf extracts exhibited antioxidant activity.
Antimicrobial (Antibacterial, Antifungal)	<i>Aristolochia indica</i> , <i>Azimatetracantha</i> , <i>Capparis zeylanica</i> , <i>Corallocarpusepigaeus</i> (Methanolic tuber extracts against gram-negative bacteria), <i>Lawsoniainermis</i> (Against antibiotic-resistant strains)	India, Bangladesh, Sri Lanka, Nepal, India, Africa, Madagascar, Philippines, Sri Lanka, India, Sri Lanka, Bangladesh, Malaysia, Africa, Persian Gulf, India, Morocco, India	Neutralizes snake venom effects. Inhibits bacterial and fungal growth. Treats acute and chronic ulcers. Methanolic tuber extracts were effective against gram-negative bacteria. Effective against antibiotic-resistant strains.
Anticancer	<i>Aristolochia indica</i> (Anti-tumor), <i>Azimatetracantha</i> , <i>Capparis zeylanica</i> (Induces apoptosis), <i>Corallocarpusepigaeus</i> (Anti-melanoma), <i>Elytraria acaulis</i> (Induces cell cycle arrest)	India, Bangladesh, Sri Lanka, Nepal, India, Africa, Madagascar, Philippines, Sri Lanka, India, Sri Lanka, Bangladesh, Malaysia, Africa, Persian Gulf, India, Shaded and arid environments	Inhibits tumor growth. Exhibits cytotoxicity. Induces apoptosis in cancer cells. Inhibits melanoma cell growth. Induces cell cycle arrest.
Anti-diabetic	<i>Alangiumsalviifolium</i> (Fruits), <i>Cadabafruticosa</i> , <i>Diplocyclospalmatus</i> , <i>Grewia hirsuta</i>	India, China, Philippines, India (worldwide), Africa, Asia, Malaysia, India and warmer regions	Fruits possess anti-diabetic activity. Regulates postprandial hyperglycemia. Inhibits enzymes related to hyperglycemia. Potential for treating diabetes.
Analgesic/Anti-inflammatory	<i>Azimatetracantha</i> , <i>Corallocarpusepigaeus</i> , <i>Lawsoniainermis</i>	India, Africa, Madagascar, Philippines, Sri Lanka, Africa, Persian Gulf, India, Morocco, India	Exhibits analgesic activity. Exhibits anti-inflammatory and anti-arthritic effects. Analgesic and anti-inflammatory effects.
Antiulcer	<i>Capparis zeylanica</i>	India, Sri Lanka, Bangladesh, Malaysia	Treats acute and chronic ulcers.
Anthelmintic	<i>Balanites aegyptiaca</i> (Vermicidal), <i>Corallocarpusepigaeus</i> (Anti-steroidogenic), <i>Elytraria acaulis</i> (Disrupts energy metabolism)	Africa, Middle East, India, Africa, Persian Gulf, India, Shaded and arid environments	Vermicidal properties. Anti-steroidogenic by suppressing steroidogenesis enzymes. Disrupts energy metabolism in helminths.
Hepatoprotective	<i>Balanites aegyptiaca</i> , <i>Capparis zeylanica</i> , <i>Elytraria acaulis</i>	Africa, Middle East, India, India, Sri Lanka, Bangladesh, Malaysia, Shaded and arid environments	Protects against hepatotoxicity. Hepatoprotective properties.
Wound Healing	<i>Capparis zeylanica</i> , <i>Lawsoniainermis</i>	India, Sri Lanka,	Promotes wound healing.





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		Bangladesh, Malaysia, Morocco, India	Accelerates burn wound healing.
Other Activities	Aristolochia indica (Abortifacient, anti-venom), Butea monosperma (Antifertility, antidiarrheal), Cadabafruticosa (Antineoplastic), Diplocyclospalmatus (Anti-quorum sensing, anticonvulsant, antiarthritic), Elytraria acaulis (Larvicidal, ovicidal), Ficus racemosa (Anti-obesity, anti-quorum sensing)	India, Bangladesh, Sri Lanka, Nepal, India, Burma, Ceylon, India (worldwide), Africa, Asia, Malaysia, Shaded and arid environments, Africa, Asia, Australia, Bangladesh, Cambodia, China	Complete abortifacient activity. Reduces fertility, antibacterial, induces apoptosis in cancer cells. Potential antifungal activity. Disrupts biofilm formation, manages convulsions, exhibits antiarthritic effects. Larvicidal and ovicidal activity. Inhibits lipase for anti-obesity, down regulates quorum sensing.

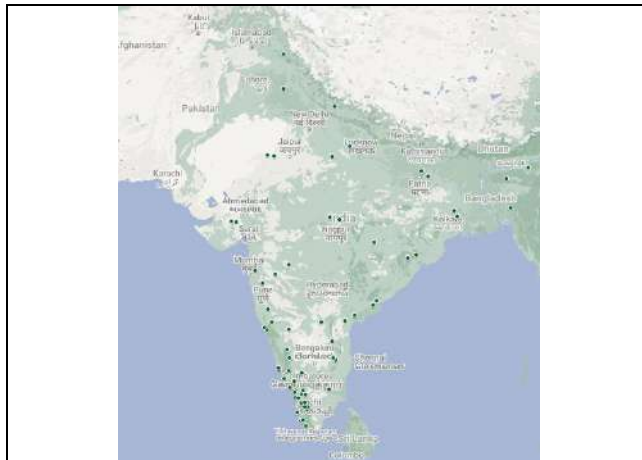


Figure 1: Green Dots in the figure represents: *Alangium salvifolium*, *Aristolochia indica*, *Azimatetracantha*, *Balanites aegyptiaca*, *Butea monosperma*, *CadabaFruticosa*, *Capparis Zeylanica*, *Corollocarpusepigaeus*, *Diplocyclospalmatus*, *Elytraria acaulis*, *Ficus racemose*, *Grewia hirsute*, and *Lawsoniainermis*.



Figure 2: *Alangium salvifolium*



Figure 3: *Aristolochia indica*



Figure 4: *Azimatetracantha*





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Figure 5: *Balanites aegyptiaca*



Figure 6: *Butea monosperma*



Figure 7: *Cadabafruticosa*



Figure 8: *Capparis Zeylanica*



Figure 9: *Lawsonia inermis*





Pythagorean Fuzzy Assignment Problem by using Matrix One's Assignment Technique

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ABSTRACT

In this work, Matrix one's assignment technique is introduced to resolve a Pythagorean fuzzy assignment problem. Score function is used for defuzzification and an algorithm of the suggested method is presented. A numerical example is illustrated with the new technique. This technique provides an optimal solution.

Keywords: Pythagorean fuzzy set, Pythagorean fuzzy assignment problem, Score function, Matrix one's assignment technique

INTRODUCTION

Assignment problem is a subclass of transportation problem, in that jobs are assigning to the workers with the one to one correspondence and the objective is to assign all tasks such that the total assignment cost is minimized. Fuzzy concepts are nowadays used in all fields, which was introduced by Lotfi Zadeh[10] for solving imprecision vagueness problems. Fuzzy sets are sets whose elements have degrees of membership grades. Intuitionistic fuzzy sets was introduced by Krassimir Atanassov[1] which is as an extension of fuzzy set, whose elements have degrees of membership and non-membership grades. In 2013, Yager[9] introduced Pythagorean fuzzy subsets. The PFS are more comprehensive than IFS. Ghadle.K.P and Muley. Y.M[2] were proposed Revised one's assignment method for solving assignment problem. Hadi Basir zadeh,[3] was introduced One's assignment method for solving assignment problems. Jeyalakshmi. K, Chitra. L, Veeramalai. G et al.,[4] found the Monalisha technique for solving Pythagorean fuzzy transportation problem. Geometric mean with Pythagorean fuzzy transportation problem[5] and simplified





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presentation of a new computing procedure for solving the fuzzy Pythagorean transportation problem was proposed by Kumar. R , Edalatpanah . S.A etal[6]. Sathya geetha .S, selvakumari. K, [7] found parallel moving method for solving for solving Pythagorean fuzzy transportation problem. Trupti A Thakre , Onkar K Chaudhari etal., proposed matrix one’s assignment method for solving fuzzy assignment problem. In this paper, Matrix one’s assignment method is proposed to solve Pythagorean fuzzy assignment problem by using score function. In section 1 introduction and section 2 preliminaries are given. In section 3 proposed method and in section 4 numerical example is illustrated. In section conclusion is given.

PRELIMINARIES

Fuzzy set

If X is an universe of discourse and x is a particular element of X , then a fuzzy set A defined on X and can be written as a collection of ordered pairs

$$A = \{(x, \mu_{\hat{A}}(x)), x \in X\}$$

Where $\mu_{\hat{A}}(x)$ is called the membership function which maps each element of X to a value between 0 and 1.

Intuitionistic Fuzzy Set

Let X be a non empty set. An intuitionistic fuzzy set I^i of X is defined as

$$I^i = \{(x, \mu_{I^i}(x), \nu_{I^i}(x)); x \in X\}$$

Where the function $\mu_{I^i}(x) : X \rightarrow [0,1]$ and $\nu_{I^i}(x) : X \rightarrow [0,1]$ define the degree of membership and the degree of non-membership functions $x \in X$ and $0 \leq \mu_{I^i}(x), \nu_{I^i}(x) \leq 1, \forall x \in X$

Pythagorean Fuzzy Set

Let X be a universal set. Then a Pythagorean fuzzy set \hat{A}^P , defined by the following:

$$\hat{A}^P = \{(x, \mu_{\hat{A}^P}(x), \mathcal{G}_{\hat{A}^P}(x)); x \in X\}, \text{ where the functions } \mu_{\hat{A}^P}(x) : X \rightarrow [0,1] \text{ and } \mathcal{G}_{\hat{A}^P}(x) : X \rightarrow [0,1]$$

define the degree of membership and the define the degree of non-membership, respectively, of the element $x \in X$,

$$0 \leq (\mu_{\hat{A}^P}(x))^2 + (\mathcal{G}_{\hat{A}^P}(x))^2 \leq 1 \text{ Suppose } 0 \leq (\mu_{\hat{A}^P}(x))^2 + \mathcal{G}_{\hat{A}^P}((x))^2 \leq 1, \text{ then there is a degree of}$$

indeterminacy of $x \in X$ to A defined by $\pi_{\hat{A}^P}(x) = \sqrt{1 - [(\mu_{\hat{A}^P}(x))^2 + (\mathcal{G}_{\hat{A}^P}(x))^2]}$ and $\pi_{\hat{A}^P}(x) \in [0,1]$. It

follows $(\mu_{\hat{A}^P}(x))^2 + (\mathcal{G}_{\hat{A}^P}(x))^2 + (\pi_{\hat{A}^P}(x))^2 = 1$ Otherwise $\pi_{\hat{A}^P}(x) = 0$ whenever

$$(\mu_{\hat{A}^P}(x))^2 + (\mathcal{G}_{\hat{A}^P}(x))^2 = 1.$$

Ranking Method

The score and accuracy function of Pythagorean fuzzy numbers are as follows:

$$S(\hat{a}^P) = \frac{1}{2} [1 - (\mu_{\hat{A}_s^P})^2 - (\mathcal{G}_{\hat{A}_s^P})^2]$$

1. Score function:

$$H(\hat{a}^P) = (\mu_{\hat{A}_s^P})^2 + (\mathcal{G}_{\hat{A}_s^P})^2$$

2. Accuracy function:





Pythagorean fuzzy number

A pair denoted by $\hat{a}^P = (\mu_{\hat{A}^P}, \mathcal{G}_{\hat{A}^P})$ is called Pythagorean fuzzy number. The degree of indeterminacy is given as

$$\pi_{\hat{A}^P}(x) = \sqrt{1 - [(\mu_{\hat{A}^P}(x))^2 + (\mathcal{G}_{\hat{A}^P}(x))^2]}$$

Pythagorean Fuzzy Assignment Problem

Consider the situation of assigning ‘n’ machines to ‘n’ jobs and each machine is capable of doing any job at different costs. Let C_{ij} be an Pythagorean fuzzy cost of assigning the j^{th} job to the i^{th} machine. Let X_{ij} be the decision variable denoting the assignment of the machine i to the job j. The objective is to minimize the total Pythagorean fuzzy cost of assigning all the jobs to the available machines (one machine per job) at the least total cost. In this situation number of rows equal to number of columns then the problem is called balanced assignment problem otherwise it is called unbalanced assignment problem. The objective function is to,

$$\text{Minimize } Z^P = \sum_{i=1}^n \sum_{j=1}^n C_{ij}^P X_{ij}$$

$$\text{Subject to } \sum_{j=1}^n x_{ij} = 1 \text{ for } i = 1, 2, \dots, n$$

$$\sum_{i=1}^n x_{ij} = 1 \text{ for } j = 1, 2, \dots, n$$

$$x_{ij} = 0 \text{ or } 1$$

Proposed approach of Pythagorean fuzzy Assignment Problem

Step 1:

Test whether the given Pythagorean fuzzy Assignment problem is balanced or not.

- (i) If it is a balanced one (i.e., the number of row is equal to the number of column) then go to step 3.
- (ii) If it is an unbalanced one (i.e., the number of row is not equal to the number of column) then go to step 2.

Step 2:

Introduce dummy rows and /or dummy columns with zero Pythagorean fuzzy costs to form a balanced one.

Step 3:

Find the rank of each cell C_{ij} of the chosen Pythagorean fuzzy cost by using the score function .

Step 4:

In a minimization (maximization) problem, find the minimum (maximum) element of each row (say d_i) then divide each element of the i^{th} row of the matrix by d_i which will create of at least one ones in each rows.

Step 5:

Find the minimum (maximum) element of each column in the assignment table (say e_j) and then divide each element of the j^{th} column o by e_j which will create at least one ones in each column. In terms of ones make the assignment. If no feasible assignment can be achieved from step 4 and step 5 then go to step 6.

Step 6:

Draw the minimum number of lines to cover all the ones . If the number of drawn lines is exactly equal to n, then the complete assignment is obtained else the complete assignment is not possible and then go to step 7.



**Senbagam et al.,****Step 7:**

Select the smallest (largest) element (say g_{ij}) which do not lie on any of the lines in the above table and divide each element of the uncovered rows or columns by g_{ij} . This will result in creating some new ones to this row or column. If still a complete optimal assignment is not achieved, then use step 7 and step 6 iteratively. By repeating the same procedure the optimal assignment will be obtained.

Numerical Example

Consider the following Pythagorean fuzzy assignment problem. Find the optimal solution.

Solution

In the given Pythagorean fuzzy assignment problem, number rows are equal to number of columns. Hence the given problem is balanced one. By using the score function, we get the following crisp value.

CONCLUSION

In this paper, Balanced Pythagorean fuzzy assignment problem is considered and which is defuzzified by using score function. Then from the crisp table, we get the ideal arrangement by utilizing the Matrix one's task strategy. This technique is appropriate for most extreme task issue too. This technique especially straight forward and its computational strategy are exceptionally basic.

REFERENCES

1. Atanassav. K, Intuitionistic Fuzzy Sets .Fuzzy sets and systems. 20(1) (1986) ,87 - 96.
2. Ghadle.K.P and Muley. Y.M, Revised one's assignment method for solving assignment problem. Journal of Statistics and Mathematics. (2013),147-150.
3. Hadi Basir zadeh, One's assignment method for solving assignment problems. Applied Mathematical sciences. (2012),2345 – 2355.
4. Jeyalakshmi. K, Chitra. L, Veeramalai. G etal., Pythagoren fuzzy transportation problem via Monalisha technique. Annals of Romanian society for cell biology. (2021).
5. Krishna Prabha. S , Sangeetha . S etal., Geometric mean with Pythagorean fuzzy transportation problem. Turkish journal of computer and mathematics education. (2021),1171 – 1176.
6. Kumar. R, Edalatpanah . S.A etal., A Pythagorean fuzzy approach to the transportation problem. Complex and intelligent systems.(2019),255 – 263.
7. Sathya geetha .S, selvakumari. K, A new method for solving Pythagorean fuzzy transportation problem. Palarch'sjournalof archaeology of Egypt/ Egyptology. (2020).
8. Trupti A Thakre , Onkar K Chaudhari etal., Placement of staff in LIC using fuzzy assignment problem. International journal of Mathematics trends and technology. (2018).
9. Yager R.R, Pythagorean fuzzy subsets. In: 2013joint IFSA world congress and NAFIPS annual meeting (IFSA/NAFIPS).(2013),57 – 61.
10. Zadeh. L. A, Fuzzy sets .Information and control. 8(3) (1965) 338 - 353.





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Table-1

	P_1	P_2	P_3	P_4
J_1	(0.7,0.2)	(0.4,0.4)	(0.5,0.3)	(0.2,0.8)
J_2	(0.1,0.9)	(0.5,0.4)	(0.6,0.3)	(0.8,0.2)
J_3	(0.5,0.4)	(0.6,0.3)	(0.7,0.2)	(0.4,0.5)
J_4	(0.8,0.2)	(0.9,0.1)	(0.4,0.6)	(0.3,0.7)

Table – 2

	P_1	P_2	P_3	P_4
J_1	0.235	0.34	0.33	0.16
J_2	0.09	0.295	0.275	0.16
J_3	0.295	0.275	0.235	0.295
J_4	0.16	0.09	0.24	0.21

Find the minimum element of each row,

	P_1	P_2	P_3	P_4
J_1	0.235	0.34	0.33	0.16
J_2	0.09	0.295	0.275	0.16
J_3	0.295	0.275	0.235	0.295
J_4	0.16	0.09	0.24	0.21

Now, divide each element of the i^{th} row by minimum element, we get,

	P_1	P_2	P_3	P_4
J_1	1.46	2.12	2.06	1
J_2	1	3.27	3.25	1.77
J_3	1.25	1.17	1	1.25
J_4	1.77	1	2.66	2.33





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Find the minimum element of each column ,

	P_1	P_2	P_3	P_4
J_1	1.46	2.12	2.06	1
J_2	1	3.27	3.25	1.77
J_3	1.25	1.17	1	1.25
J_4	1.77	1	2.66	2.33

Then divide each element of the j^{th} column, we get the following table values

	P_1	P_2	P_3	P_4
J_1	1.46	2.12	2.06	1
J_2	1	3.27	3.25	1.77
J_3	1.25	1.17	1	1.25
J_4	1.77	1	2.66	2.33

Hence the complete assignment table is as follows,

	P_1	P_2	P_3	P_4
J_1	1.46	2.12	2.06	[1]
J_2	[1]	3.27	3.25	1.77
J_3	1.25	1.17	[1]	1.25
J_4	1.77	[1]	2.66	2.33

Hence the allocations are,

$$J_1 \rightarrow P_4, J_2 \rightarrow P_1, J_3 \rightarrow P_3, J_4 \rightarrow P_2$$

$$\begin{aligned} \text{Minimum assignment cost} &= 0.16+0.09+0.235+0.09 \\ &= 0.575 \end{aligned}$$





A Comprehensive Analysis of Stock Price Prediction using Machine Learning Techniques

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ABSTRACT

Stock price prediction is the process of forecasting future movements in the prices of stocks traded on financial markets. It involves analysing historical price data, along with various fundamental and technical indicators, to make predictions about future price trends. Stock price prediction is a critical aspect of investment decision-making, as it helps investors and traders anticipate market movements and adjust their portfolios accordingly. The use of multi-feature supervised reinforcement learning methods in the stock trading area is thoroughly reviewed in this work. The two methods of supervised and unsupervised reinforcement learning is combined in supervised reinforcement learning. The former uses labelled data to its advantage, while the latter optimizes behaviours via trial and error. Because of its ability to understand intricate patterns in financial data and make smart trading choices, this method has attracted a lot of interest in the stock trading industry. This article reviews 34 research papers for Stock price prediction and explores the potential of computer-assisted methods for Stock price prediction and staging. This literature review summarizes previous work on stock trading multi-feature supervised reinforcement learning approaches, discussing their benefits, drawbacks, and future research directions. In addition, the article delves into the difficulties of putting these methods into practice and provides suggestions for how they improved and adjusted to meet the ever-changing demands of the financial markets.



**Deepa and Murugesakumar**

Keywords: The two methods of supervised and unsupervised reinforcement learning are combined in supervised reinforcement learning.

INTRODUCTION

In the last several years, there have been tremendous breakthroughs in the use of machine learning methods in the financial markets, namely in stock trading. Supervised reinforcement learning, which combines the strengths of supervised and reinforcement learning, is one of these methods that has shown promise for improving trading decision-making [1-5]. By using labelled historical data to direct learning and optimizing actions via trial and error, supervised reinforcement learning allows the system to adapt to changing market circumstances. We provide a thorough analysis of the use of multi-feature supervised reinforcement learning methods to the stock trading area in this work [6-9]. By adding various features or indicators from financial data, such as price movements, trading volumes, and technical indicators, multi-feature supervised reinforcement learning expands the traditional reinforcement learning framework and captures more complex market patterns and relationships [10-14]. Stock price prediction is the process of forecasting future movements in the prices of stocks traded on financial markets. It involves analysing historical price data, along with various fundamental and technical indicators, to make predictions about future price trends [15-19]. Stock price prediction is a critical aspect of investment decision-making, as it helps investors and traders anticipate market movements and adjust their portfolios accordingly. Techniques used for stock price prediction range from traditional statistical methods such as time series analysis to advanced machine learning algorithms like neural networks and reinforcement learning [20-25]. The goal of stock price prediction is to gain insights into potential price movements, enabling investors to make informed decisions and manage their investment risks effectively. Trading methods, risk mitigation, and return maximization can all be greatly improved with the use of multi-feature supervised reinforcement learning in the stock market [26-29]. These methods enhance traders' and investors' ability to make decisions by capturing complicated market dynamics and adapting to new circumstances using a varied range of attributes. We hope that by reviewing the literature on the topic, we can shed light on the many ways that multi-feature supervised reinforcement learning has been applied to the stock trading industry. By reviewing the relevant literature, we want to shed light on the efficacy and practical consequences of these methods in actual trading situations by analysing their strengths, weaknesses, and empirical results [30-35].

LITERATURE SURVEY

Advancements in Stock Market Prediction Techniques a Comprehensive Review

Ali, et al. (2023) the intriguing and challenging field of stock market index prediction attracts data scientists and practitioners. The stock markets were the lifeblood of every economy, thus accurate stock market forecasting was crucial for governments and investors alike to ensure maximum profit. The main points and conclusions of this study were presented and summarized in this section. Researchers in earlier works used a single time series or machine learning model to accurately forecast stock price values, which led to criticism of their prediction abilities. Finding a novel way to reliably predict the KSE-100 index's daily closing prices was the major objective of this research. Ampomah, E.K., et al. (2020) these authors research analyzed and contrasted six distinct tree-based ensemble machine learning methods for forecasting stock price movement direction. Three separate stock exchanges were randomly surveyed for their stock data. A training set and a test set were created for every datum. The training set was used to assess the models' performance using ten-fold cross validation accuracy. Accuracy, precision, recall, f1-score, specificity, and area under the curve (AUC) were additional metrics used to assess the models on the test set. Ansari, et al. (2022) Developing a profitable trading strategy was essential for automated trading systems, where an algorithm or computer programmed executes stock trades. Creating automated trading systems capable of making lucrative judgments was a major area of study for financial market traders. In order to make the best possible judgments while selling or purchasing stocks, this study proposes a decision support system for automated stock



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market trading. Dhivya, M. and Maniraj, V (2024) the nonlinear, noisy, and volatile nature of stock market data makes accurate price forecasting difficult. Stock market prediction refers to the practice of trying to judge the future worth of a company's shares or comparable financial instruments traded on an exchange. Investors can increase their financial market profit with the use of accurate stock market price forecasts. The suggested approach makes use of pre-trained data obtained from the Huge Stock Market Dataset and a pre-trained model called modified ResNet-50, which was based on transfer learning. Ding, G., & Qin, L. (2020) In order to forecast several stock values at once, this study proposes an LSTM-based deep recurrent neural network model called an Associated Net. The author lay forth the concept, the algorithm, and the experimental setup. When compared to other models, such as the LSTM network model and the LSTM deep recurrent neural network model, the Associated Net's practicability and accuracy were confirmed. In order to ensure that the Associated Net model was applicable, many data sets were used. According to the results of the experiments, the Associated Net model has the best average accuracy out of the three models. Kabbani et al. (2022) In order to determine the best stock market trading strategy, this paper introduced a Deep Reinforcement Learning method that integrates sentiment research with technical indicators. The results demonstrate that the agent's performance has been much enhanced with the incorporation of sentiment scores of news headlines and technical indicators into the state representation. Additionally, they demonstrate that a continuous action space was preferable to a discrete one for solving the trading issue. Additionally, the author investigated the possibility of addressing the portfolio allocation issue by the use of an Actor-Critic method (TD3).

Advancements in Stock Market Prediction Techniques

Khan, W., et al. (2023) Using news and social media as external inputs, this study proposes a methodology for predicting future trends in the stock market. The author looked at how social media and financial news affected market forecasting for the next 10 days. The author discovered that social media has a stronger impact on stock prediction on day 9, when sentiment traits were taken into account. On the other hand, financial news had a stronger impact on day 9, followed by day 8. After three days of integrating social media sentiment with financial news, the author found that although the top accuracy dropped, most classifiers' overall accuracies went up. Li, M., et al. (2023) The author provide a deep learning model for stock price time series that was augmented by clustering in this research. Incorporating stock clustering into the price prediction framework and using four similar parameters to execute the framework were these authors aims for high accuracy deep learning forecasting. In particular, the author suggest a new weighted DTW similarity metric with logistic distribution probability density function, LWDTW, to group stocks that were comparable in order to perform efficient clustering. Luo, X. (2024) these authors research uses CNN and SVR as two methodologies to predict stock prices; the main results show that closing prices will remain volatile, although there was still a little upward tendency. Another advantage of the SVR model over the CNN model was its increased accuracy. Those looking to invest might consider purchasing Moutai shares. This study compares and contrasts the two prediction models using real-world data. In addition, investors can use the paper's study conclusion, which includes a basic trend projection for Moutai stock, as a reference when making investment selections. Mehtab, S., & Sen, J. (2020) Using a combination of eight regression and eight classification algorithms, this research presents many ways to predicting stock price and movement on a weekly forecast horizon.

Appropriate preprocessing of the raw data and identification of appropriate variables for the construction of predictive models were completed. The prediction framework was enhanced by constructing three Convolutional Neural Network models using univariate and multivariate techniques, changing input data size, and network topologies. These models were built after the machine learning and deep learning-based models have been designed and tested. Mehtab, et al. (2020) Using eight ML models and four LSTM-based deep learning regression models, this research presents several methods for predicting the values and patterns of stock indexes on a weekly forecast horizon. The author built, optimized, and tested the prediction models using the daily historical data of NIFTY 50 index values from December 29, 2014, to July 31, 2020. After the raw data underwent data wrangling and pre-processing, a set of derived variables was generated to facilitate model construction. Moghar, A. and Hamiche, M., (2020) these authors research presents an LSTM-based RNN that can predict the future prices of GOOGL and NKE assets; these authors model has shown encouraging results. The results of the tests confirm that these authors model can follow the movement of the initial values of the two assets. These authors goal moving forward was to optimize



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these authors' assets for maximum prediction accuracy by determining the optimal settings for bout data length and number of training epochs. Muhammad, T., et al. (2023)The main achievement of this article was the presentation of a machine learning model that utilizes transformers to forecast the future values of stocks traded on the Dhaka Stock Exchange (DSE). For general issues in signal processing and time series analysis, a comparable method developed. The experimental findings demonstrate that these models were capable of achieving low error rates that meet satisfaction, even when run quickly.

Recent Advances in Stock Market Prediction Techniques

Mukherjee, et al. (2023)In order to forecast stock market indexes and stock prices, this research suggests two methods. During the training phase, this research employs a Feed-forward Neural Network and employs the back propagation algorithm. In addition to providing a visual representation of the expected outcome of the forecast, this model offered essential insight into the trend of the prediction. Although it took a lot of training data and epochs, these authors model eventually produced satisfactory manufacturing results with an average prediction accuracy of 97.66%. Furthermore, the regularization approach was used to address the issue of over fitting. So, this research provides an additional, less harmful way to get around the expense of comprehensive training. Pang, X., et al. (2020)based on the LSTM neural network, this research proposes an LSTM neural network with an embedded layer and an LSTM neural network with an automated encoder. To start, the author checks the models' accuracy using Sinopec and the Shanghai A-share composite index. After that, for the remaining stocks, the author uses an improved ELSTM model. Compared to the stochastic prediction, the A-share composite index stands at 57% and the average accuracy of the three stocks was 53.2%. Overall, the predictive performance of the Shanghai A-share composite index was improved when using the methodologies discussed in this study. Qiu, et al. (2020)to foretell stock market opening prices, this article builds a forecasting system. The author achieved remarkable results in predicting the opening price of stocks by processing their data using a wavelet transform and applying an attention-based LSTM neural network. These authors suggested model outperforms popular LSTM, GRU, and LSTM neural network models with wavelet transform in terms of fitting degree and prediction accuracy, according to the experimental data. As a result, the model was competitive with current models and offers vast application potential.

Selvakumar, S. K., et al. (2024)Machine learning and its strong algorithms have recently made their way into market research and stock market prediction, where these approaches were being used to analyse stock market data. For any given day, you can see the stock's initial price, its highest and lowest values, and its closing price. Stock market forecasting used to be a laborious and error-prone operation. Time and resources were both saved and process performance was enhanced via the application of machine learning. Sidogi, et al. (2023)These authors research here lays forth a method for predicting stock prices by analysing limit order book data for characteristic route patterns. When comparing LOB data from two separate exchanges conducted at separate periods, the outcomes have been inconsistent. Signature routes do not work well as features for LOB stream data to stock price prediction owing to increased model prediction error, as seen in the more current NASPERS stream data, in contrast to the earlier AMAZON data, which demonstrated superior performance. Théate, T. and Ernst, D., (2021)To solve the algorithmic trading issue of finding the ideal trading position at any given moment in stock market trading, this scientific research study introduces the Trading Deep Q-Network algorithm (TDQN), a deep reinforcement learning (DRL) solution. This novel trading method outperforms the benchmark trading strategies on average, according to a thorough performance evaluation. Torres EP, et al. (2020)three primary contributions were made in this paper. This dataset, which will be accessible to the public, was the first. The second was engaging in stock market trading, which was both innovative and dynamic in its ability to evoke emotions. Because the experiment replicated real-life trading settings in a virtual environment, each participant encountered novel market circumstances. The suggested technique elicited feelings that were then labelled according to valence-arousal criteria. A mood of relaxation (high valence - low arousal), hope (high valence - high arousal), regret or sadness (low valence - low arousal), and dread (low valence - high arousal) were the main emotions associated with the categories. Vijn, Mehar, (2020)The intricate patterns formed by the constant changes in stock prices, which were based on a myriad of factors, make stock market return prediction a difficult undertaking. There were insufficient characteristics in the historical dataset that was accessible on the company's website. These elements include the following: high, low, open, close, adjacent close



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value of stock prices, volume of shares traded, etc. Using the current variables, new ones have been constructed to get a better forecasted pricing value. The author utilize ANN to forecast the stock's closing price the next day, and the author employ RF for comparison analysis. Wen HR, et al. (2024) Predicting the stock's closing price the next day using past data was the goal of this paper's research on the topic of stock price prediction. The stock market has significant cyclic tendencies, as the author have seen. With this goal in mind, the author present the mWDN-LSTM model, built on deep neural networks that can make effective and accurate use of stock market cyclical patterns. The adaptive parameter adjustment mechanism of mWDN and redesign of the convolution matrix mitigate the impact of the boundary problem in wavelet decomposition on prediction performance. Additionally, these authors mWDN LSTM model avoids data leakage through a sliding window mechanism, setting it apart from other DWT-based hybrid models. Yadav A et al. (2020) the first experiment evaluated four businesses' LSTMs—ICICI, TCS, Reliance, and Maruti—using stateful and stateless architectures. When it comes to the stock price prediction issue that was used for the experiment, the differences between stateful and stateless LSTM were not statistically significant, according to the P-values. Every LSTM run includes random seeding, which causes little fluctuations in output but accounts for most of the observed value differences. Stateless people have a smaller standard deviation and spread than state complete people, according to the box and whisker plot.

Bi-LSTM

To classify stock price predictions, Bidirectional Long Short-Term Memory (Bi-LSTM) networks are used because of their capacity to grasp long-term relationships in sequential data. Two Long Short-Term Memory (LSTM) layers make up this design; one processes the input sequence forwards in time, while the other processes it backwards in time. This allows the model to understand both the past and the future. Back Propagation through Time (BPTT) trains Bi-LSTMs to minimize a loss function, and for a given sequence of input data, the resulting probability distributions across alternative classes like "buy," "sell," or "hold" are provided. Model performance can be fine-tuned by modifying hyper parameters or applying regularization methods; evaluation measures including as accuracy, precision, recall, and F1 score provide insight into this process. If you're looking for a reliable method to classify stock price predictions, Bi-LSTMs are a great choice. They can accurately estimate future price movements by capturing complex patterns in past data.

Decision tree

To use a decision tree algorithm to categories future price movements of stocks using pertinent attributes and past data is the process of stock price prediction categorization using decision trees. Data cleansing, addressing missing numbers, and creating key elements like technical indicators or financial ratios are all part of data preparation, the first step in the process. After that, the decision tree algorithm is taught to work with a labelled dataset, where each data point stands for past characteristics and has a class label that predicts how the price will go in the future. To achieve this goal, the decision tree method iteratively uses feature values to split the feature space into regions, with the goal of making each subset as pure as possible in relation to the class labels. The decision tree learns to use the feature values to make judgments at each internal node during training. At the end, the anticipated class labels are represented by the leaf nodes. When the decision tree model has been trained, it can be used to forecast the class labels for previously unknown data points. Metrics like recall, accuracy, precision, and F1 score are used to assess the decision tree model's performance on a distinct testing or validation dataset. To enhance the model's performance and generalizability, fine-tuning strategies like pruning or modifying hyper parameters can be used. Decision trees, in general, provide a clear and understandable method for classifying stock price projections, which helps analysts and investors to comprehend the reasoning behind the model's forecasts and make educated choices.

Temporal Convolutional Networks

Classifying stock price predictions with the use of Temporal Convolutional Networks (TCNs) is drawing on CNNs' capacity to detect patterns in sequential data that are related to time. Several time-series forecasting jobs have shown success using TCNs, which are built to handle sequential data. Before the TCN model can be fed historical stock price data, the data must first be prepared for use in the model. Data partitioning into windows of predetermined length or the use of dilated convolutions to detect interdependencies at greater distances are two possible approaches. In





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addition, useful characteristics like emotion scores or technical indications can be retrieved and used as input features. The next step is to build the TCN model, which usually includes many convolutional layers, pooling layers to lower dimensionality, and nonlinear activation functions like ReLU (Rectified Linear Unit). Skip connections and residual connections are additional components of the TCN design that can enhance training stability and enable gradient flow. As it trains, the TCN model learns to anticipate price changes by extracting temporal information from input sequences. To achieve this, methods like Stochastic Gradient Descent (SGD) and Adam optimization are used to optimize a selected loss function, such as categorical cross-entropy.

DISCUSSION

In this study, we survey the literature on multi-feature supervised reinforcement learning approaches, which integrate the best of both supervised and unsupervised learning, and their use in the stock trading environment. Because of its ability to understand intricate patterns in financial data and make smart trading choices, this hybrid technique has attracted a lot of interest. The review highlights the strengths, limits, and possible future research directions by synthesizing the current literature on different approaches. A potential paradigm for optimizing stock trading techniques that use both historical data and real-time feedback is supervised reinforcement learning. Stock price forecasts can be taught using labelled data, and then updated in real-time using market feedback by means of reinforcement learning algorithms. Traders are able to make better, more flexible selections using this combination, which might boost their performance and increase their profits. But there are a number of problems with putting these methods into practice in the real world that the study points out. Developing strong and dependable trading techniques can be challenging due to the non-stationary and intrinsic complexity of financial markets. Not to mention the fact that there can be data quality and availability issues, regulatory restraints, and market dynamics to think about. Figure 4 and Table 4 show the results of a comparison of the accuracy of stock price prediction algorithms used by various writers. While Khan et al. used Random Forest to get an accuracy of 83.22%, Ding and Qin used RNN-LSTM to get a 95% success rate. However, the maximum accuracy of 97.66% was attained by Mukherjee et al., who used Artificial Neural Networks (ANN). Here we see how several machine learning strategies fared in forecasting stock values; among the methods tested, ANN proved to be the most accurate.

CONCLUSIONS

The study concludes with an in-depth analysis of how multi-feature supervised reinforcement learning approaches, which combine the best of supervised and reinforcement learning, are applied to the world of stock trading. Because of its capacity to help traders make educated judgments based on complex patterns in financial data, this hybrid method has attracted a lot of interest. The review highlights the strengths, weaknesses, and potential for future research of various techniques by analysing and synthesizing the current literature on the subject. In order to address the ever-changing nature of financial markets, the debate also explores the difficulties of actual implementation and offers suggestions for improvements and adjustments. Consequently, the study does double duty: it sheds light on where things are in the field of supervised reinforcement learning as it pertains to stock trading, and it lays the groundwork for future innovations in this area.

REFERENCES

1. Behera and A. Chinmay, "Stock Price Prediction using Machine Learning," 2022 International Conference on Machine Learning, Computer Systems and Security (MLCSS), Bhubaneswar, India, 2022, pp. 3-5, doi: 10.1109/MLCSS57186.2022.00009.





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2. Ali, Muhammad, Dost Muhammad Khan, Huda M. Alshanbari, and Abd Al-Aziz Hosni El-Bagoury. "Prediction of complex stock market data using an improved hybrid emd-lstm model." *Applied Sciences* 13, no. 3 (2023): 1429.
3. Ampomah, E.K., Qin, Z. and Nyame, G., 2020. Evaluation of tree-based ensemble machine learning models in predicting stock price direction of movement. *Information*, 11(6), p.332.
4. Ansari, Yasmeeen, Sadaf Yasmin, Sheneela Naz, Hira Zaffar, Zeeshan Ali, Jihoon Moon, and Seungmin Rho. "A deep reinforcement learning-based decision support system for automated stock market trading." *IEEE Access* 10 (2022): 127469-127501.
5. N. Varaprasad, C. Kundan Kanth, G. Jeevan and Y. K. Chakravarti, "Stock Price Prediction using Machine Learning," 2022 *International Conference on Electronics and Renewable Systems (ICEARS)*, Tuticorin, India, 2022, pp. 1309-1313, doi: 10.1109/ICEARS53579.2022.9752248.
6. Dhivya, M. and Maniraj, V., 2024. Predicting Daily Stock Market Price using a Few-shot and Modified Transfer Learning. *International Journal of Intelligent Systems and Applications in Engineering*, 12(5s), pp.400-408.
7. Ding, G., & Qin, L. (2020). Study on the prediction of stock price based on the associated network model of LSTM. *International Journal of Machine Learning and Cybernetics*, 11, 1307-1317.
8. G. Bathla, "Stock Price prediction using LSTM and SVR," 2020 *Sixth International Conference on Parallel, Distributed and Grid Computing (PDGC)*, Wagnaghat, India, 2020, pp. 211-214, doi: 10.1109/PDGC50313.2020.9315800.
9. G. Shao, "Stock price prediction based on multifactorial linear models and machine learning approaches," 2022 *IEEE Conference on Telecommunications, Optics and Computer Science (TOCS)*, Dalian, China, 2022, pp. 319-324, doi: 10.1109/TOCS56154.2022.10016086.
10. Han, C. and Fu, X., 2023. Challenge and opportunity: deep learning-based stock price prediction by using Bi-directional LSTM model. *Frontiers in Business, Economics and Management*, 8(2), pp.51-54.
11. P. C. Purnama, N. L. W. S. R. Ginantra, I. W. A. S. Darma and I. P. A. E. D. Udayana, "Comparison of Support Vector Machine (SVM) and Linear Regression (LR) for Stock Price Prediction," 2023 *Eighth International Conference on Informatics and Computing (ICIC)*, Manado, Indonesia, 2023, pp. 1-6, doi: 10.1109/ICIC60109.2023.10381982.
12. Kabbani, Taylan, and Ekrem Duman. "Deep reinforcement learning approach for trading automation in the stock market." *IEEE Access* 10 (2022): 93564-93574.
13. Khan, W., Ghazanfar, M.A., Azam, M.A., Karami, A., Alyoubi, K.H. and Alfakeeh, A.S., 2020. Stock market prediction using machine learning classifiers and social media, news. *Journal of Ambient Intelligence and Humanized Computing*, pp.1-24.
14. L. M and P. Gnanasekaran, "Prediction of Stock Price Using Machine Learning (Classification) Algorithms," 2023 *International Conference on Advances in Computing, Communication and Applied Informatics (ACCAI)*, Chennai, India, 2023, pp. 1-5, doi: 10.1109/ACCAI58221.2023.10199307.
15. L. Mathanprasad and M. Gunasekaran, "Analysing the Trend of Stock Market and Evaluate the performance of Market Prediction using Machine Learning Approach," 2022 *International Conference on Advances in Computing, Communication and Applied Informatics (ACCAI)*, Chennai, India, 2022, pp. 1-9, doi: 10.1109/ACCAI53970.2022.9752616.
16. Li, M., Zhu, Y., Shen, Y. and Angelova, M., 2023. Clustering-enhanced stock price prediction using deep learning. *World Wide Web*, 26(1), pp.207-232.
17. Luo, X. (2024). Research on stock price prediction of Kweichow Moutai based on machine learning methods. *Highlights in Business, Economics and Management*, 24, 258-262.
18. Mehtab, S., & Sen, J. (2020). Stock price prediction using convolutional neural networks on a multivariate timeseries. *arXiv preprint arXiv:2001.09769*.
19. Mehtab, Sidra, Jaydip Sen, and Abhishek Dutta. "Stock price prediction using machine learning and LSTM-based deep learning models." In *Machine Learning and Metaheuristics Algorithms, and Applications: Second Symposium, SoMMA 2020, Chennai, India, October 14–17, 2020, Revised Selected Papers 2*, pp. 88-106. Springer Singapore, 2021.





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20. Moghar, A. and Hamiche, M., 2020. Stock market prediction using LSTM recurrent neural network. *Procedia Computer Science*, 170, pp.1168-1173.
21. Muhammad, T., Aftab, A.B., Ibrahim, M., Ahsan, M.M., Muhu, M.M., Khan, S.I. and Alam, M.S., 2023. Transformer-based deep learning model for stock price prediction: A case study on Bangladesh stock market. *International Journal of Computational Intelligence and Applications*, p.2350013.
22. Mukherjee, Somenath, Bikash Sadhukhan, Nairita Sarkar, Debajyoti Roy, and Soumil De. "Stock market prediction using deep learning algorithms." *CAAI Transactions on Intelligence Technology* 8, no. 1 (2023): 82-94.
23. P. S. Lakshmi, N. Deepika, V. Lavanya, L. J. Mary, D. R. Thilak and A. A. Sylvia, "Prediction of Stock Price Using Machine Learning," 2022 International Conference on Data Science, Agents & Artificial Intelligence (ICDSAAI), Chennai, India, 2022, pp. 1-4, doi: 10.1109/ICDSAAI55433.2022.10028862.
24. Pang, X., Zhou, Y., Wang, P., Lin, W., & Chang, V. (2020). An innovative neural network approach for stock market prediction. *The Journal of Supercomputing*, 76, 2098-2118.
25. Qiu, Jiayu, Bin Wang, and Changjun Zhou. "Forecasting stock prices with long-short term memory neural network based on attention mechanism." *PloS one* 15, no. 1 (2020): e0227222.
26. S. Ravikumar and P. Saraf, "Prediction of Stock Prices using Machine Learning (Regression, Classification) Algorithms," 2020 International Conference for Emerging Technology (INCET), Belgaum, India, 2020, pp. 1-5, doi: 10.1109/INCET49848.2020.9154061.
27. S. Sarode, H. G. Tolani, P. Kak and C. S. Lifna, "Stock Price Prediction Using Machine Learning Techniques," 2019 International Conference on Intelligent Sustainable Systems (ICISS), Palladam, India, 2019, pp. 177-181, doi: 10.1109/ISSI.2019.8907958.
28. Selvakumar, S. K., Ashok, V., Selvadurai, J. J., Ebenezer, V., Nivin, A. J., & Aron, D. A. (2024). Divination of stock market exploration using long short-term memory (LSTM). *Multidisciplinary Science Journal*, 6(1), 2024001-2024001.
29. Sidogi, Thendo, Wilson Tsakane Mongwe, Rendani Mbuva, Peter Olukanmi, and Tshilidzi Marwala. "A Signature Transform of Limit Order Book Data for Stock Price Prediction." *IEEE Access* (2023).
30. Théate, T. and Ernst, D., 2021. An application of deep reinforcement learning to algorithmic trading. *Expert Systems with Applications*, 173, p.114632.
31. Torres EP, Torres EA, Hernández-Álvarez M, Yoo SG. Emotion recognition related to stock trading using machine learning algorithms with feature selection. *Ieee Access*. 2020 Nov 3;8:199719-32.
32. Vijh, Mehar, et al. "Stock closing price prediction using machine learning techniques." *Procedia computer science* 167 (2020): 599-606.
33. Wen HR, Yuan M, Wang S, Liang L, Fu X. A Multilevel Wavelet Decomposition Network Hybrid Model Utilizing Cyclic Patterns for Stock Price Prediction. *Complexity*. 2024 Jan 17;2024.
34. Yadav A, Jha CK, Sharan A. Optimizing LSTM for time series prediction in Indian stock market. *Procedia Computer Science*. 2020 Jan 1;167:2091-100.
35. Hewage, P., Behera, A., Trovati, M., Pereira, E., Ghahremani, M., Palmieri, F., & Liu, Y. (2020). Temporal convolutional neural (TCN) network for an effective weather forecasting using time-series data from the local weather station. *Soft Computing*, 24, 16453-16482.

Table 1: Comparison of Stock Trading Methodologies using Machine Learning

Author	Year	Methodology	Limitations	Advantages
Yang, et al.	2020	Deep Reinforcement Learning	The strategy's capacity to be applied to a wider variety of assets or markets was limited when it was focused on certain equities.	To better respond to shifting markets, dynamically pick the top-performing agent.
Yoo, Joon Soo.	2024	Artificial Intelligence	Adaptability to changes in the market was hindered since effectiveness was dependent on	Automated stock trading was made more accurate using AI-driven DRL, leading to more precise predictions.





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			high-quality and relevant historical data.	
Zaheer, S., et al.	2023	RNN	The selection and significance of input characteristics might affect the model's performance.	Extensive investor research was facilitated by a hybrid deep-learning algorithm that forecasts both low and high prices.
Zhang et al.	2020	Deep Reinforcement Learning	Algorithms for Deep Reinforcement Learning (RL) provide new ideas for trading strategies.	While this study mainly focuses on linear utility functions, other functions – perhaps tailored to risk-averse investors – can be the subject of future investigations.
Zhao, et al.	2023	Machine Learning	Limitations in generalizability can arise from the difficulty of comparing performance across different datasets.	Investment risk can be mitigated and profits can be enhanced using data-driven stock predictions.

Table 2: Comparative Analysis of Stock Trading Methodologies using different algorithms

Author	Year	Methodology	Limitations	Advantages
Torres EP, et al.	2020	Random Forest	Potentially affecting relevance was the gap between theoretical trading and actual emotional responses.	By building a huge dataset and using sophisticated categorization, the research improves emotional intelligence in traders and pioneers emotion elicitation in stock trading.
Vijh, Mehar,	2020	Random Forest Regression	To prevent over fitting or under fitting, it was critical to balance the complexity of the model.	Incorporating suggestions for financial news items shows a proactive attitude.
Wen HR, et al.	2024	CNN	Results were only shown to work on certain datasets, thus they can't be applied to other markets with different properties.	With a sliding window technique, the model prevents data leakage, guaranteeing practical dependability in real-world circumstances.
Wolff et al.	2024	Machine Learning	The models' sensitivity to particular market situations was rarely investigated, despite their consistency.	Even STOXX Europe 600 has had positive outcomes, proving that ML models can be used to a wide variety of markets.
Yadav A, et al.	2020	LSTM	Shows that more study was needed to create uniform rules for LSTM setup; falls short in this regard.	Recognizes the importance of context, implying that stateful LSTMs might work better in certain language modeling situations than others.

Table 3: comparison table for Merits and Demerits for Various Algorithms

Algorithm	Merits	Demerits
ARIMA	Time series analysis is a good fit for ARIMA models because of its foundation in sound statistical concepts. As is typical of stock price time series, they adjust for the data's autocorrelation and seasonality.	Due to their linear character, ARIMA models can have difficulty capturing the intricate nonlinear correlations seen in stock price data. Therefore, they could struggle in situations where the dependencies between the variables being predicted and the outcome variable are very nonlinear.





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Recurrent Neural Networks	Due to their ability to grasp temporal connections across time steps, RNNs work well with sequential data, such as stock prices. This paves the way for the modeling of intricate data patterns and trends, including both short- and long-term variations.	In particular, for deep architectures or big datasets, RNN training can be computationally demanding. Consequently, RNN model deployment and maintenance might need substantial computing resources and infrastructure, which could pose a financial burden for certain applications.
Generative Adversarial Networks	Generated artificial neural networks (GANs) are quite good at creating fake data that looks a lot like genuine data distributions. It is possible to train GANs to produce synthetic stock price data for use in stock price prediction, which mimics the statistical features and dynamics of actual market data. Predictive models can benefit from using this generated data to supplement their training dataset.	When training GANs, mode collapse can occur, causing the generator network to output restricted variants of synthetic samples rather than capturing the complete variety of the data distribution. When it comes to stock price prediction, mode collapse might cause the model to produce unrealistically similar trajectories, which can lower its efficacy.

Table 4: Existing author’s accuracy comparison chart

Author	Method used	Accuracy
Ding, G., & Qin, L.	RNN-LSTM	95
Khan, W. et al.	Random forest	83.22
Mukherjee et al.	ANN	97.66

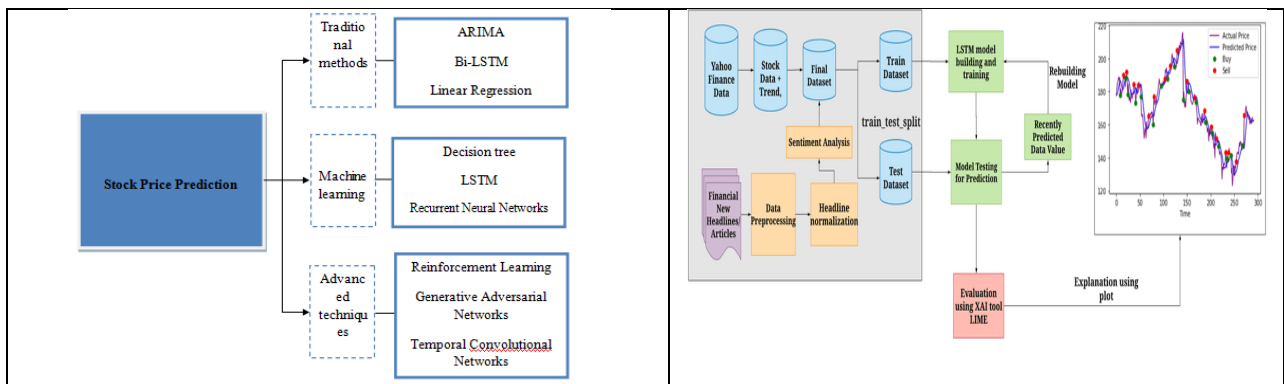


Figure 1: Popular methods

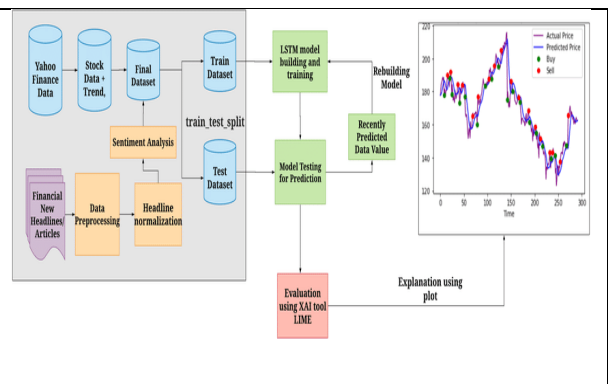


Figure 2: Bi-LSTM architecture [Source: https://www.researchgate.net/figure/System-Architecture-of-Stock-Market-Prediction-using-LSTM-and-XAI-Shows-how-the-data-is_fig2_348847477]





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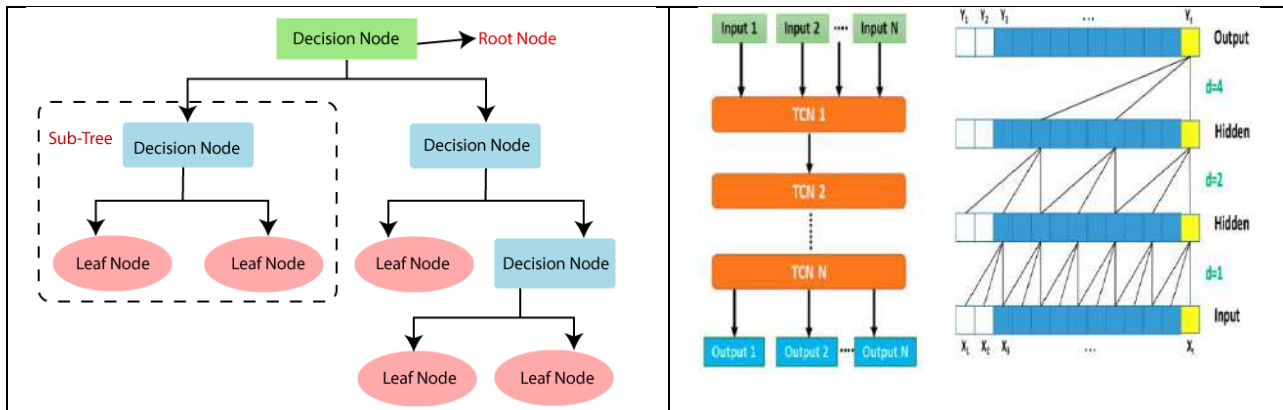


Figure 3: Decision tree architecture [Source: <https://www.javatpoint.com/machine-learning-decision-tree-classification-algorithm>]

Figure 4: Temporal Convolutional Networks architecture [Hewage, P. et al. (2020)]

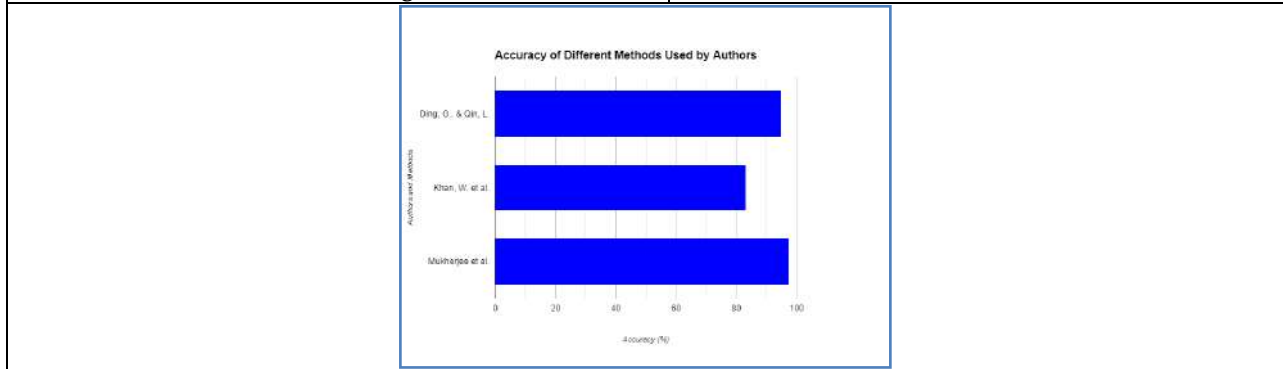


Figure 5: accuracy comparison chart





InceptionV3 in Healthcare: Automated Human Disease Classification

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ABSTRACT

Nails can be valuable for disease identification in humans as they often display visible symptoms of systemic conditions like anemia, fungal infections, and psoriasis. Changes in nail color, texture, and structure can serve as early indicators, allowing healthcare professionals to diagnose underlying diseases and initiate timely treatment. InceptionV3, a deep learning model, classifies human nail diseases from images using a complex convolutional neural network. It extracts intricate features from nail images, distinguishing various diseases through patterns, textures, and shapes. InceptionV3 enables accurate disease classification, aiding in early diagnosis and effective treatment planning for nail-related conditions. Inception-V3 transfer learning model was principally used in this work to classify human illness from nail images, leading to the creation of an effective computer-aided diagnosis tool. This approach improves illness prediction speed and diagnosis accuracy. After applying data augmentation, features were extracted using a refined Inception-V3 model developed using transfer learning. Then, for classification, Softmax classifiers are used. Other pretrained models were compared to the outcomes. This experiment demonstrated the value of transfer learning for categorizing human diseases by surpassing other approaches and reaching the greatest accuracy of 99.07% and 87.07% during training and testing respectively. With the VGG-16 method, we obtained an accuracy of 94.27% for comparison.

Keywords: InceptionV3, Medical Image Processing, Deep Learning, Disease Classification, CNN.



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INTRODUCTION

The primary component of human nails is metabolized keratin, which builds up on the skin's surface constantly. Nails display a variety of looks depending on age, metabolism, and season, which can be used as general health indicators. Normal characteristics of healthy nails are a bright pink colour, a smooth texture, and no ridges. Examining the existence of vertical or horizontal lines, fissures, or colour changes on the nail's surface might help identify any potential health issues. However, for those without any expertise identifying nails, self-detecting nail health might be difficult. To resolve this issue, we automatically classified the nail photos using a deep learning inceptionV3 classification model. We believe that by utilizing the capabilities of this sophisticated deep learning model, it will be able to provide a useful categorization method. In this manuscript, we employ the transfer learning approach to reconfigure the Inception-v3 model with the Nail image dataset. Through this methodology, we have successfully created an efficient classification model for human diseases, accomplishing superior accuracy levels within a brief training period. The subsequent sections of this document are structured as follows: In Part II, we delve into a discussion of relevant prior research on classification techniques. Part III outlines the steps involved in constructing our human disease classification model. Lastly, in Part IV, we substantiate the model's effectiveness through experimental validation.

LITERATURE REVIEW

There are essentially two categories for previous studies on the categorization of nail disorders. First, several research endeavored to offer recommendations for identifying nail problems. These recommendations were largely made to help doctors recognize lesions in clinical settings, either by direct observation or by using nail dermoscopy [1-4]. However, this method necessitated that doctors have extensive training in their field and experience working with a wide range of patients. Furthermore, these rules frequently depended on visual cues, rendering them open to individual interpretation [5-8]. Due to the inherent uncertainty resulting from variable sampling circumstances, such as variations in illumination, imaging equipment specs, and picture resolutions, these approaches were not suitable for real-world applications. Due to this uncertainty, the sampled pictures had frequent noise problems that had a major negative influence on the quality of the analysis results and prevented the development of trustworthy criteria for nail melanoma identification [9]. As a result, there was another category of research projects devoted to using different computer vision techniques and algorithms. In the past, traditional machine learning techniques were often used for medical picture recognition. A multiclass support vector machine (SVM), for instance, was used by Maniyan et al. [10] to identify nail disorders in the early stages using hand nail photos. With an average accuracy of almost 90%, their model provided combined predictions for the categorization of 23 distinct nail illnesses rather than making individual forecasts for numerous classes. However, as deep learning gained popularity across a wide range of industries, several researchers started to progressively use these methods to help with medical picture diagnosis.

Convolutional neural networks (CNNs) were used by Winkler et al. [11] to offer a unique method for classifying different varieties of nail melanoma. The use of six dermoscopic image datasets, which improved the robustness of CNN-based nail lesion classification, was their noteworthy contribution. In the set-SSM, set-NM, and set-LMM datasets, their CNN performed remarkably well, obtaining approximately 93% sensitivity and 65% specificity. Its capacity to categorize the remaining three datasets, however, was significantly constrained. A hybrid CNN was used in a different research by Nijhawan et al. [12] to extract features instead of more conventional machine learning models like the Support Vector Machine (SVM), K-Nearest Neighbour (KNN), and Random Forest (RF). This study's accuracy rate for classifying a total of 11 different nail lesion types was 84.58%. Additionally, other studies emphasized CNNs for single-category categorization. For instance, to categorize subungual melanoma, Mehra et al. [13] used a CNN using the VGG-16 architecture. With their indoor dataset, they showed promising results and highlighted how effectively using transfer learning algorithms reduced GPU consumption and dataset size. Comparing these computer vision-based methodologies to more conventional visually-based assessment techniques,



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they produced amazing levels of accuracy. Nevertheless, reservations about CNN-based approaches lingered. CNN's fundamental constraint, which categorizes each picture, made it difficult for it to offer objective characteristics that could efficiently transmit thorough information and measurements of lesions. Such information was not especially helpful in clinical practice but is essential for doctors to perform in-depth analysis. Machine learning and deep learning techniques may have trouble classifying entire nail pictures of fingers and toes if they just consider the texture and properties of the nail itself. The skin around the nails and background objects in the photograph may affect how well the image is classified. Segmentation models have so been frequently used to overcome this problem. Examples worth mentioning are the Mask R-CNN model developed by He et al. [15] and the U-Net introduced by Ronneberger et al. [14]. These models are excellent at defining object boundaries, making the attributes the model has learnt visible, and enabling the efficient segmentation of lesions, which in turn helps with clinical diagnosis. Hsieh et al. [16] took use of the Mask R-CNN deep learning model's capabilities for example segmentation. They used a specialized technique for segmenting and rating the severity of nail psoriasis images. With an amazing accuracy of 91.5%, our algorithm successfully separated six different nail psoriasis presentations from nail datasets and carried out severity analysis in line with the Nail Psoriasis Severity Index (NAPSI) evaluation technique.

METHODOLOGY

This section demonstrates how we plan to carry out this project. Dataset, Data Preprocessing, Model Description, Classification Result are its four primary subsections. Figure 1 shows how our work was carried out in a visual manner. The next section contains a full discussion of each of the five subsections stated above.

DATASET

In this study, we have gathered a total of 18,736 nail images, which are organized into ten distinct categories as outlined in Table 1.

DATA AUGMENTATION

In this study, we used preprocessing methods such horizontal and vertical mirroring, rotations between -20 and +20 degrees and -45 and +45 degrees, and scaling to 0.5 and 1.5 times the original size of the photos. To improve the model's capacity to generalize across a variety of imaging situations, several augmentation procedures were used. Table 2 shows the results of these augmentations in visual form.

MODEL DESCRIPTION

The InceptionV3 model, originally developed by Google, is a deep convolutional neural network specially tailored for image processing tasks. It consists of multiple inception modules that enable it to capture intricate image features at different scales. In the context of nail image processing for human disease classification, InceptionV3 serves as a powerful tool. It learns to detect subtle patterns and anomalies in nail images, aiding in the accurate diagnosis of various diseases. Its robust architecture and pre-trained weights on extensive datasets make it an efficient choice for classifying human diseases based on nail images, enhancing diagnostic accuracy and healthcare outcomes. Convolutional neural network categorization models include Inception-v3, which automatically resizes images to 224 by 224 pixels. Inception-v3 greatly decreases the amount of network model parameters by not averaging connections from the AlexNet layer for pooling, in contrast to AlexNet in this network design. Asymmetric convolution kernels are also used to increase feature extraction variety.

RESULTS AND DISCUSSION

EVALUATION CRITERIA

In this study, a model's performance is evaluated using a variety of performance criteria. We make use of measurements like the F1 Score, Accuracy, Precision, Recall, and Confusion Matrix. The Confusion Matrix offers a





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thorough assessment of model performance by delivering insights into important variables including True Positives, False Positives, True Negatives, and False Negatives.

True Negative (TN): When both the actual and anticipated values were negative.

True Positive (TP): When both the actual and projected values were positive.

False Negative (FN): When a number is actually positive but is expected to be negative.

False Positive (FP): When a positive result is anticipated but the actual value is negative.

$$\text{Accuracy} = (\text{TP} + \text{TN}) / (\text{TP} + \text{TN} + \text{FP} + \text{FN}) \quad (1)$$

$$\text{Specificity} = \text{TN} / (\text{TN} + \text{FP}) \quad (2)$$

$$\text{Recall} = \text{TP} / (\text{TP} + \text{FN}) \quad (3)$$

$$\text{Precision} = \text{TP} / (\text{TP} + \text{FP}) \quad (4)$$

$$\text{F1} = 2\text{TP} / (2\text{TP} + \text{FP} + \text{FN}) \quad (5)$$

COMPARISON OF DIFFERENT TYPE OF CNN MODEL

The capacity of a classifier to discriminate between classes is quantified by the area under the curve, as shown above table. An improved classifier's performance is shown by a higher accuracy value. Accuracy values, which range from 0 to 1, are an important assessment statistic. InceptionV3 in above Table 3 (a) stands out because it has the greatest accuracy value, which is 99.07% and (b) stands for accuracy value, which is 96.27%. Below Table 4 shows performance of models. Table 4 indicates that the InceptionV3 model has the best test accuracy. Thus, the most accurate classifier for this issue is InceptionV3. It displayed the confusion matrix of prediction results in Figure 2. The matrix's diagonal side reflected the testing samples' real positive predictions, whereas the other sections represented the false positives that were misclassified. Since no model was flawless, misclassification was inevitable, but the percentage of misclassification allowed for the identification of each class's prediction accuracy. Misclassified samples were dispersed across the InceptionV3 result confusion matrix, particularly in the class of Yellow and Copper nails, which had the highest false positive rates of misclassification. As for the cause, it was thought that the 2 classes of samples had traits in common with other nail in terms of look and pattern. Consequently, there were more false positives in the 2 classes' predictions.

CONCLUSION

In the future, we will train our model using images of excellent quality, and we will include resampling to our model to address the problem of data imbalance. To enhance the identification of human diseases, we intend to construct a variety of integrated models. Along with InceptionV3, we'll employ many algorithms and methods for the integration, including MobileNetV2, Efficient NetB7, ResNet50 etc.

REFERENCES

1. B. Richert, P. Lecerf, M. Caucanas, and J. André, "Nail tumors," *Clinics in Dermatology*, Vol. 31, No. 5, pp. 602-617, 2013.
2. V. J. James, "Fibre diffraction of skin and nails provides an accurate diagnosis of malignancies," *Int J Cancer*, Vol. 125, No. 1, pp. 133-145, 2009.
3. G. Hinds, and V. D. Thomas, "Malignancy and Cancer Treatment-Related Hair and Nail Changes," *Dermatologic Clinics*, Vol. 26, No. 1, pp. 59-68, 2008.
4. B. M. Piraccini, F. Bruni, and M. Starace, "Dermoscopy of non-skin cancer nail disorders," *Dermatologic Therapy*, Vol. 25, No. 6, pp. 594-602, 2012.
5. D. L. Perruchoud, C. Varonier, E. Haneke, R. E. Hunger, H. Beltraminelli, L. Borradori, and A. Ehnis Pérez, "Bowen disease of the nail unit: a retrospective study of 12 cases and their association with human papillomaviruses," *Dermatology and Venereology*, Vol. 30, No. 9, pp. 1503- 1506, 2016.
6. K. A. Mannava, S. Mannava, L. A. Koman, L. RobinsonBostom, and N. Jellinek, "Longitudinal melanonychia:








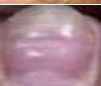



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detection and management of nail melanoma,” *Hand Surgery*, Vol. 18, No. 1, pp. 133-139, 2013.

7. I. R. Bristow, and D. A. de Berker, “Development of a practical guide for the early recognition for malignant b melanoma of the foot and nail unit,” *Journal of Foot and Ankle Research*, Vol. 3, No. 1, 2010.
8. H. Koga, T. Saida, and H. Uhara, “Key point in dermoscopic differentiation between early nail apparatus melanoma and benign longitudinal melanonychia,” *The Journal of Dermatology*, Vol. 38, No. 1, pp. 45-52, 2011.
9. T. S. Indi, and Y. A. Gunge, "Early Stage Disease Diagnosis System Using Human Nail Image Processing," *International Journal of Information Technology and Computer Science (IJITCS)*, Vol. 7, pp. 30-35, 2016.
10. P. Maniyan, and B. L. Shivakumar, "Detection of Diseases using Nail Image Processing Based on Multiclass SVM Classifier Method," *International Journal of Engineering Science and Computing (IJESC)*, Vol. 8, No. 5, pp. 17382- 17390, 2018.
11. J. K. Winkler, K. Sies, C. Fink, F. Toberer, A., Enk, and T. Deinlein, et. al., “Melanoma recognition by a deep learning convolutional neural network—Performance in different melanoma subtypes and localisations,” *European Journal of Cancer*, Vol. 127, pp. 21–29, 2020.
12. R. Nijhawan, R. Verma, Ayushi, S. Bhushan, R. Dua and A. Mittal, "An Integrated Deep Learning Framework Approach for Nail Disease Identification," 2017 13th International Conference on Signal-Image Technology & Internet-Based Systems (SITIS), pp. 197-202, 2017.
13. M. Mehra, S. D’Costa, R. D’Mello, J. George and D. R. Kalbande, "Leveraging Deep Learning for Nail Disease Diagnostic," 2021 4th Biennial International Conference on Nascent Technologies in Engineering (ICNTE), pp. 1-5, 2021.
14. O. Ronneberger, P. Fischer, and T. Brox, “U-net: Convolutional networks for biomedical image segmentation,” *Medical Image Computing and Computer Assisted Intervention (MICCAI)*, pp. 234-241, 2015.
15. K. He, G. Gkioxari, P. Dollar, and R. Girshick, “Mask rcnn,” arXiv preprint arXiv:1703.06870, 2017.
16. K. Y. Hsieh, H. Y. Chen, S. C. Kim, H. Y. Chiu, and G. Y. Chen, "A Mask R-CNN Based Automatic Assessment System for Nail Psoriasis Severity," *Computers in Biology and Medicine*, Vol. 143, 2022.
17. A. Dutta, A. Zisserman, “The VIA annotation software for images, audio and video,” *Proceedings of the 27th ACM International Conference on Multimedia*, pp. 2276–2279, 2019.

Table 1: Classes of Nail Database

Image Classes	Class name	No. of Images	Sample Image
1	Black	2612	
2	Blue	1449	
3	Copper	3234	
4	Grey	543	
5	Green	1154	
6	Purple	356	
7	Red	1395	





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8	White	3778	
9	Yellow	3504	
10	Healthy	711	
Total No. of images		18736	

Table 2: Result of Augmentation








		
Original Image		
		
Rotation from -15 to +15	Rotation from -45 to +45	Scale of 1.5
		
Scale of 0.5	Mirroring Image	Upside Down

Table 3: Model Accuracy

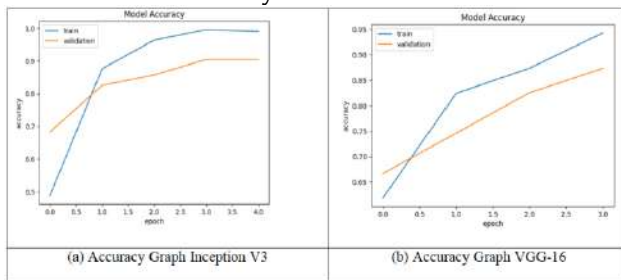


Table 4: Performance of InceptionV3 and VGG16

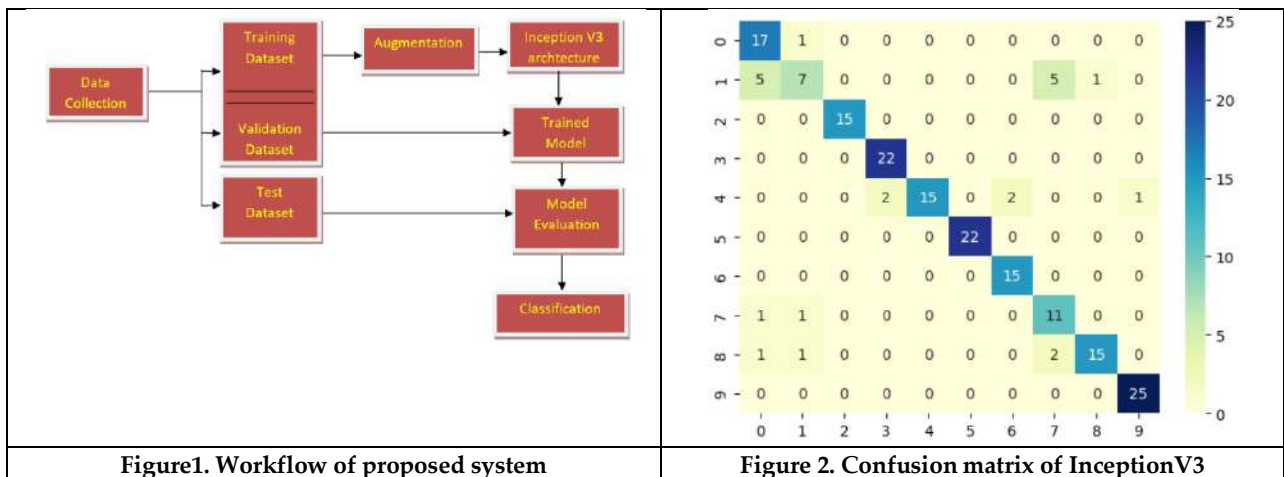
Model Name	Test Accuracy	Class	Precision	Recall	F1 score
InceptionV3	0.8770	0	0.71	0.94	0.81
		1	0.70	0.39	0.50
		2	1.00	1.00	1.00
		3	0.92	1.00	0.96
		4	1.00	0.75	0.86
		5	1.00	1.00	1.00
		6	0.88	1.00	0.94
		7	0.61	0.85	0.71
		8	0.94	0.79	0.86
		9	0.96	1.00	0.98





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VGG 16	0.8235	0	0.62	0.77	0.69
		1	0.65	0.55	0.59
		2	0.92	0.92	0.92
		3	1.00	1.00	1.00
		4	0.82	0.90	0.86
		5	0.94	0.94	0.94
		6	1.00	0.92	0.96
		7	0.64	0.41	0.50
		8	0.52	0.85	0.65
		9	1.00	1.00	1.00





A Review on Arsenic Contamination of Groundwater in Kolkata, West Bengal, India: Sources, Effects and Probable Methods of Mitigation

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ABSTRACT

Water is an essential matter to life. The accessibility of good quality water is the basic need for the water based ecosystem, food security and for sustainable development. However in present days, the quality of water is despoiled due to arsenic contamination in groundwater. Increasing arsenic contamination in the ground water is one of the major environmental challenges that the Bengal delta is facing today. In present days, groundwater is the major source of drinking water for a large number of the population in this region. Therefore, the significant presence of toxic arsenic in groundwater has a direct consequence on human lives. Moreover, toxic arsenic compounds also easily enter into the food chain via the consumption of agricultural products grown in this area. There are a number of diseases like Melanesia, Keratosis, Hyperkeratosis, skin cancer etc. which are caused by the drinking of arsenic contaminated water. So, the efficient route of stable and long serving arsenic remediation is highly essential to keep people safe. In this article, a comprehensive municipal ward wise map of the arsenic contaminated shallow groundwater of Kolkata region, probable sources of arsenic in water, its effects on humans, feasible mitigation methods etc. are discussed in detail.

Keywords: Ground water, contamination, arsenic, acute toxicity, chronic toxicity, human health.



**Asik Hossian****INTRODUCTION**

Arsenic bearing minerals are abundant in the Earth's crust which gradually dissolve in groundwater from tough rocks and soils. If the groundwater is consumed directly without any further purification, arsenic easily enters the human body. Beyond a certain threshold level, arsenic is enormously toxic for the human body [1, 2, 3, 4]. Exposure to arsenic can cause skin cancer, cancer of the bladder, diabetes, and lung diseases [5]. It can also affect the photosynthesis of plants and prove lethal to several aquatic organisms. The contamination problem of arsenic in the shallow groundwater of eastern India and Bangladesh is being discussed to some extent [1]. In many places, the contamination level is substantially more than the comfortable contamination level set by the Government of India (50 µg/L)[6]. However, it is undoubtedly higher in most of the places if the limit set by the World Health Organization (WHO) (10 µg/L) is considered [7]. Many investigations have been carried out by various research groups regarding the level of arsenic contamination in groundwater in West Bengal [8, 9, 10, 11]. The Public Health and Engineering Department [PHED], West Bengal also organized a survey of groundwater arsenic contamination in the year 2004-2005 (Fig. 1: data has been taken from PHED, West Bengal in 2004) [10] by collecting samples from eight districts of West Bengal. However, this survey did not include the city of Kolkata and therefore, no quantitative detailed information about the arsenic contamination in the ground water of Kolkata was available. In 2009, for the first time the Chakraborti group [12] comprehensively studied the groundwater arsenic contamination of Kolkata, where water samples from 100 municipal wards out of 141 wards (no. of wards during 2009 was 141, now it is 144) were collected and tested. The report shows that 30 wards (21.2 %) have arsenic contamination above 50 µg/L (Indian standard), and 65 wards had arsenic contamination above 10 µg/L (46.1 %) (WHO standard). However, even in this detailed quantitative ward-wise data on exact degree of arsenic contamination was measured but any expressive statistical analysis was not reported. Recently, some research groups have shown a detailed experimental analysis on arsenic contamination in ground water in Kolkata where its level increases day by day [13, 14]. Kolkata city has been expanding her eastern boundary pretty rapidly for the last few years and the population increases due to this expansion. However, this eastern area does not get adequate treated pure water supply till now as all the active surface water treatment plants are placed along the west border line of the city, just beside the river Ganges. Therefore, a significant rise in the groundwater drawing has been observed in the eastern part of the city in the last few years. It has been well documented for the way of increasing groundwater level along with decreasing restore rate which can expressively increase the arsenic contamination in the shallow groundwater and this contamination can also interfere to the deeper groundwater level and from this it can also contaminate the surface water over the shallow groundwater [15, 16, 17, 18, 19, 20]. Therefore, there is serious scientific and public attention needed to study details for the growth of the groundwater map of Kolkata in the last few years, which may benefit to take quick learned action from the administration.

STUDY AREA

Kolkata is placed at longitude 88° 30' E, latitude 22° 33' N, and at 6.4 m above the sea level. The area under the administrative control of Kolkata Municipal Corporation (KMC) is 205 km² with a total population of 4,496,694 as per 2011 census. All the water samples were collected exhaustively from all the wards. Mainly, the samples were collected from hand tube wells in the KMC region, having an average bore depth of 45-60 m. Among the 144 wards under Kolkata Municipal Corporation (KMC), 100 have considerably higher arsenic contamination in water than the limits thought safe by the World Health Organization (WHO) [13].

INSTRUMENTATION

The quantitative analysis of Arsenic was performed in a laboratory-based ICP-OES instrument [Perkin-Elmer USA, Optima 2100 DV] ensuing standard protocol of sample analysis [13].

RESULTS AND DISCUSSION

The groundwater arsenic contamination of Kolkata has changed significantly since 2009. From details studied it has been found that the wards under arsenic contamination threat have increased in number day by day [13, 14]. 100



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wards out of 144 wards in KMC have alarming levels of arsenic contamination in their unconfined shallow water table. Out of 100 wards, 51 wards have arsenic level $>50 \mu\text{g/L}$, while the level in the rest is between 11 to $50 \mu\text{g/L}$. Only 30 percent of wards (44) across the city have arsenic level $<10 \mu\text{g/L}$. It has been found that in 2009, arsenic contamination was limited to central, southeast, and western regions of the city, presently the major area in north and central Kolkata has entered the red zone and parts of south and far west Kolkata have improved with arsenic contamination less than $10 \mu\text{g/L}$ (for details see in the figure- 2, 3).

ARSENIC POISONING

Acute arsenic poisoning in groundwater may occur due to unintentional ingestion of inorganic arsenic compounds (e.g. AsO_3). Cases of poisoning are detected by deep gastrointestinal damage, resulting in severe vomiting and diarrhea which may affect shock and subsequent oliguria and albuminuria [21]. Other acute symptoms may happen within a few minutes following exposure to the poison in solution, which may be delayed for several hours if the arsenic compound is in solid form or if it is taken with a meal. The fatal dose of ingested arsenic trioxide has been reported to range from 70 to 180 mg/lit. Death may occur within 24 hours but the usual course runs from 3 to 7 days. Acute intoxication with arsenic compounds is usually accompanied by anemia and leukopenia, especially granulocytopenia etc. Exposure to irritant arsenic compounds in air, such as arsenic trioxide (AsO_3) can cause acute damage to mucous membranes of the respiratory systems and can cause acute symptoms from exposed skin. Severe irritation of the nasal mucosa, larynx and bronchi as well as conjunctivitis and dermatitis occur in such cases (WHO, 1993) [22].

Chronic arsenic poisoning is much more insidious in nature which often involves multiple hospital admissions before the right diagnosis is made. The most prominent chronic signs involve the skin, lungs, liver and blood systems. At the first time, diagnosis was made in West Bengal and Bangladesh patients of Khulna in December, 1984 [23, 24] by Prof. K. C. Saha in July 1982 at School of Tropical Medicine, Calcutta [23, 25]. With prolonged exposure to arsenic via ingestion in food, drinking water or medications, symptoms are fairly unlike from those after inhalation exposure. Among several diseases, anemia and leukopenia are almost universal with chronic arsenic exposure. Thrombocytopenia can also occur very frequently. The anemia is usually normochromic and normocytic and caused at least partially by hemolysis [26]. IARC (International Agency for Research on Cancer, 2004) has also characterized that arsenic is a human cancer causing element. Due to continuous rising arsenic fixation in drinking water, can also cause the development of arsenicosis which is collective reason for the illnesses and causes for several diseases like hyper-pigmentation, hyperkeratosis, gangrene, a few sorts of malignancies, hyperpigmentation, an abundance of skin pigmentation etc [27, 28, 29]. It has been reported that arsenic can change DNA oxidative sequence, DNA methylation process and it also causes various kinds of chromosomal distortion and protein-DNA cross connections in the human body [28, 30].

Most of the arsenic contaminated diseases were found among poor and less educated peoples in this region. Most of the public water resources including piped water supply systems were found to be contaminated with arsenic and people are drinking day by day. As there is no early noticeable symptom or sign of arsenic toxicity and most of the less conscious people are reluctant to test their water resources and continue to drink arsenic contaminated water. Due to this general lack of awareness, most of the people are silently suffering from arsenic contaminated disease in this area. Though some seriously arsenic affected people including cancer patients gave history of attending arsenic recommendation centers at Kolkata city, they failed to get admission due to lack of accommodations. Further, most of the affected patients don't have ability to pay the cost of investigation, treatment and bed rent in those hospitals prevented them from being admitted and caused immense suffering and death of many severely ill poor arsenicosis patients (different types of disease due to arsenic toxicity are shown in figure-4)[31].



**Asik Hossian****SOURCES OF ARSENIC CONTAMINATION IN WATER**

All the probable reasons for increase in arsenic contamination in groundwater in the Kolkata Municipal Corporation (KMC) regions are given below [21, 32, 33, 34, 35, 36].

1. It has been recognized that rising oxygen content is the detrimental aspect for increasing arsenic contamination in the groundwater. According to this theory, the arsenopyrite (containing As^{3+}) oxidized by oxygen and formed a hydrated iron arsenate compound known as pitticite, an As^{5+} -containing mineral of formula $\text{Fe}^{3+}_2(\text{AsO}_4)(\text{SO}_4)(\text{H}_2\text{O})$ which is water soluble. This is one of the most natural sources for increasing arsenic contamination in groundwater [37].
2. It has been found that arsenic is released in the groundwater by reduction of iron oxy-hydroxide through a microbial metabolism process which is completely opposite to the above oxidation method by oxygen. According to this theory, arsenic in form of charged As^{5+} arsenate species remains gradually absorbed on the surfaces of oxidized iron oxy-hydroxide natural nanoparticles, which tends to get released to the environment when the iron oxy-hydroxide particles get reduced through a microbial metabolism process [38].
3. The “lack of groundwater replenishment in the regions” is another most important cause for increasing arsenic contamination in groundwater.
4. Moreover, it has been found that the food chain over the consumption of agricultural products grown in this area causes arsenic contamination [39].
5. In the agricultural field and urban areas various rodenticides are used which contain arsenic and this is also a source for arsenic contamination.
6. Different factories are also responsible for increasing arsenic, where arsenic is found as a by product and the factory dumps this without appropriate safety measures.
7. The geochemical environment is generally associated with high arsenic concentration in groundwater.
8. The arsenic bearing geologic materials are one of the major causes of arsenic contamination. The presence of sulfide mineral deposits in the field and the association of arsenic with such types of minerals suggest very strongly that these are the source for the near field arsenic sources [40].
9. The upper 150 meters of the alluvial sediments has high concentrations of arsenic which may also increase the arsenic contamination.

MITIGATION METHODS

The following necessary steps should be taken for the arsenic contaminated area by all the acting bodies like health department, team of doctors, municipality authority, social workers team, and local community to inhibit further exposure of arsenic.

1. It has been detected that the major water sources like public tube wells, piped water and other water sources were contaminated with arsenic in this region. Therefore, an urgent necessary measures essential for availability of nontoxic water sources in the arsenic affected areas. Most of the people in the arsenic affected area are not aware of arsenic contamination in their daily needed home tube wells water. So to prevent further exposure of arsenic to these people frequently, camps can be organized for awareness generation and motivation of the people for testing their daily used drinking water sources for arsenic.
2. Majority of the arsenic affected people have severe skin lesions and universal appearances like lung disease, neuropathy etc. which are unbearable suffering for them. In this situation people become very helpless as they are very poor and enough hospital facilities are not accessible where they are living. Therefore, a small arrangement for free medical treatment for these patients in state appointment hospitals is also a significant movement.
3. Harvesting of rainwater is mandatory at least for every large establishment.
4. Necessary steps should have been taken for large scale artificial recharge and rainwater replenishment in the Kolkata Municipal Corporation (KMC) region.
5. Groundwater for domestic purposes can be withdrawn from only the confined deep water level.





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Finally, all the acting bodies of KMC can use the following latest modern arsenic removal technology to take out arsenic from the ground water [41, 42, 43, 44, 45, 46, 47, 48].

Oxidation

The most effective method to decontaminate the arsenic from the water is removing the pentavalent form of arsenic as arsenate form As(V). Since the trivalent form of arsenic as arsenite form As(III) is predominantly non-charged below pH 9.2. Thus arsenate is much less mobile than arsenite, as it tends to co-precipitate out with metallic cations or it adsorbson top of solid surfaces. Arsenite can be oxidized by oxygen (O₂), hypochlorite (HClO), permanganate (HMnO₄) and hydrogen peroxide (H₂O₂). Atmospheric oxygen is the most readily available oxidizing agent and many treatment processes prefer oxidation by air. However, air oxidation of arsenic is a very slow process and can take weeks for oxidation. Air oxidation of arsenite can be catalyzed by bacteria, strong acidic or alkali solutions, copper, powdered activated carbon and high temperature [49, 50, 51, 52].

Coagulation and Filtration

Coagulation and filtration method with using metal salts and lime followed by filtration is one of the most deeply documented methods of arsenic removal from water. In the process of coagulation, arsenic is removed from solution through the following three mechanisms [53, 54, 55].

- i. Precipitation: In this process insoluble compounds are formed.
- ii. Co-precipitation: By this process soluble arsenic species are incorporated into developing metal hydroxides phases [e.g. co-precipitation with Fe(III)].
- iii. Adsorption: In this process soluble arsenic can bind on external surfaces of the insoluble metal hydroxide species through electrostatic force of attraction and finally these metal hydroxide species are removed from the medium.

Sorptive Filtration

Few sorptive media like activated carbon, activated alumina, iron and manganese coated sand, kaolinite clay, hydrated ferric oxide, activated bauxite, titanium oxide and many natural and synthetic media can be used to remove arsenic from water [56].

Ion Exchange

Another most effective method to decontaminate the arsenic from the water is the ion exchange method [57]. In the ion exchange method the medium is used as synthetic resin of better-defined ion exchange capacity. The synthetic resin is based on a cross-linked polymer skeleton, called the matrix. The charged functional groups are attached to the matrix through covalent bonding and drop into acidic, weakly acidic, strongly basic and weakly basic groups. The ion exchange process is less dependent on pH of water. However, arsenite being uncharged, is not removed by the ion exchange process. Hence, pre-oxidation of As(III) to As(V) is required for removal of arsenite by ion exchange process. Ion exchange resins can be easily regenerated by washing with a NaCl solution.

Application of Nanoparticles

In recent times, developments in nanoscience and nanotechnology have enclosed the way to the synthesis of various nanomaterials for the remediation of contaminated water [58, 59, 60]. Due to their high specific surface area, high reactivity, and high specificity, nanoparticles have been given significant environmental attention as novel adsorbents of contaminants, such as arsenic and also heavy metals, from aqueous solutions. Carbon nanotubes and nanocomposites, titanium-based nanoparticles, iron-based nanoparticles, and other metal-based nanoparticles are among the most widely used and investigated nanoparticles for the treatment of arsenic contaminated water.





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CONCLUSION

Arsenic contamination in groundwater has been increasing to newer areas and presently, approximately 450 million people living in the Ganga-Meghna-Brahmaputra delta region is at threat (Maeda, 1994). The increase in population is not only related to population but it is also highly dependent on the lack of groundwater replenishment in certain regions. Therefore, artificial recharge and rainwater replenishment have become essential measures to overcome the situation. The present study suggests that the exceeding treated water service should be an urgent task of the administration for the entire population of the city for direct consumption and also it should get utmost importance to avoid interruption of toxicity in biological food chains through agricultural products. All the acting body of KMC will try to use the latest modern arsenic exclusion technology to remove arsenic from the water to prevent further exposure of arsenic and to get a healthy life. Hopefully, this study will force the urban planners to rethink the existing urbanization and development plans for all the cities located across India having arsenic contaminated groundwater.

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REFERENCES

1. P. Ravenscroft, H. Brammer, K. Richards, *Arsenic Pollution A Global Synthesis* (Wiley-Blackwell, 2009).
2. K. T. Kitchin, H. Sun, *Biological Chemistry of Arsenic, Antimony and Bismuth* 1st Edn (Wiley, 2011).
3. J. N. Parker, P. M. Parker, *Arsenic Poisoning: A Medical Dictionary, Bibliography, And Annotated Research Guide to Internet References* (ICON Health Publications, 2004).
4. W. R. Chappell, C. O. Abernathy, R. L. Calderon, *Fifth International Conference on Arsenic Exposure and Health Effects* (Elsevier, 2002).
5. M. K. Sengupta, S.C. Mukherjee, S. Pati, A. Mukherjeel, M. M. Rahman, M. A. Hossain, B. Das, B. Nayakl, A. Pal, A. Zafar, An eight-year study report on arsenic contamination in groundwater and health effects in Eruani village, Bangladesh and an approach for its mitigation, *J. Health Popul. Nutr.* 2006, 24, 129-141.
6. Arsenic in ground water in India. Central Ground Water Board, Ministry of Water Resources, Government of India, CGWB (2009).
7. Guidelines for drinking-water quality, World Health Organization, WHO (2011).
8. A. Chatterjee, D. Das, B. K. Mandal, T. R. Chowdhury, G. Samanta, D. Chakraborti, Arsenic in ground water in six districts of West Bengal, India: the biggest arsenic calamity in the world part I. Arsenic Species in Drinking Water and Urine of the Affected People, *Analyst*, 120, 643–650, 1995.
9. D. Das, G. Samanta, B. K. Mandal, T. R. Chowdhury, C.R. Chanda, P.P. Chowdhury, G. K. Basu, D. Chakraborti, Arsenic in groundwater in six districts of West Bengal, India, *Environmental Geochemistry and Health*, 18, 5-15, 1996.
10. PHE Reports (2004), Available At: <http://www.wbphed.gov.in/main/index.php/water-quality/background-wq>.
11. A. Chatterjee, D. Das, D. Chakraborti, A study of ground water contamination by arsenic in the residential area of Behala, Calcutta due to industrial pollution, *Environmental Pollution*, 80, 57–65, 1993.
12. D. Chakraborti, B. Das, M. M. Rahman, U. K. Chowdhury, B. Biswas, A. B. Goswami, B. Nayak, A. Pal, M. K. Sengupta, S. Ahamed, A. Hossain, G. Basu, T. R. Chowdhury, D. Das, Status of groundwater arsenic contamination in the state of West Bengal, India: a 20 year study report, *Molecular Nutrition & Food Research*, 53, 542-551, 2009.





Asik Hossian

13. A. Malakar, S. Islam, M. A. Ali, S. Ray, Rapid decadal evolution in the groundwater arsenic content of Kolkata, India and its correlation with the practices of her dwellers, *Environ Monit Assess*, 188(10):584, 2016.
14. D. Chakraborti, B. Das, M. M. Rahman, B. Nayak, A. Pal, M. K. Sengupta, S. Ahamed, M. A. Hossain, U. K. Chowdhury, B. K. Biswas, K. C. Saha, R. N. Dutta, *Chemosphere*, 180, 437-447, 2017.
15. D. Das, G. Basu, T. R. Chowdhury, D. Chakraborti, Arsenic in Groundwater, Calcutta, *Proc. Int. Conf.*, 1995.
16. A. K. Saha, C. Chakraborti, Arsenic in Groundwater, Calcutta. *Proc. Int. Conf.* 1995.
17. B. K. Mandal, T. R. Chowdhury, G. Samanta, D. P. Mukherjee, C. R. Chanda, K. C. Saha, D. Chakraborti, (1998). Impact of safe water for drinking and cooking on five arsenic-affected families for 2 years in West Bengal, India. *Science of the Total Environment*, 218, 185-201, 1998.
18. M. Safiuddin, M. M. Karim, Groundwater arsenic contamination in Bangladesh: causes, effects and remediation, Proceedings of the 1st IEB international conference and 7th annual paper meet; 2001 November 2-3, Chittagong, Bangladesh: Institution of Engineers, Bangladesh.
19. K. A. Radloff, Y. Zheng, H. A. Michael, M. Stute, B. C. Bostick, I. Mihajlov, M. Bounds, M. R. Huq, I. Choudhury, M.W. Rahman, P. Schlosser, K. M. Ahmed, A. van Geen, Arsenic migration to deep groundwater in Bangladesh influenced by adsorption and water demand, *Nature Geoscience*, 4, 793-798, 2011.
20. W. G. Burgess, M. A. Hoque, H. A. Michael, C. I. Voss, G. N. Breit, K. M. Ahmed, Vulnerability of deep groundwater in the Bengal aquifer system to contamination by arsenic, *Nature Geoscience*, 3, 83-87, 2010.
21. S. R. Dey, Arsenic in Surface Water of Murshidabad, West Bengal, India: An Unprecedented Situation, *Indian Journal of Biology*, 3 (1), 49-55, 2016.
22. Health Organizations, (1993), Guidelines for drinking water quality, vol. 1-Recommendation (2nd Ed.) WHO, Geneva.
23. K. C. Saha, Chronic arsenical dermatoses from tube well water in West Bengal during 1983-87, *Indian J. Dermatol*, 40(1), 1-12, 1995.
24. K. C. Saha, Arsenic poisoning from groundwater in West Bengal, *Breakthrough*, 7, No. 4, 5-14, 1998.
25. K. C. Saha, Melanokeratosis from arsenic contaminated tube well water, *Ind. J. Dermatology*, 29 (4), 37-46, 1984.
26. R. A. Kyle, G. L. Pearse, Haematological aspects of arsenic intoxication, *N. Engl. J. Med*, 273, 18-23, 1965.
27. A. H. Smith, C. Hoppenhayn-Rich, M. N. Bates, H. M. Goeden, I. Hertz-Picciotto, H. M. Duggan, Review of cancer risks from arsenic in drinking water. *Environ. Health Pers.* 97, 259-267, 1992.
28. A. Bhat, S. C. Bhat, Arsenic Pollution and Remedial Measures in West Bengal: An Overview, *Global Journal for Research Analysis*, 9, 10, 2020, DOI: 10.36106/gjra.
29. National Research Council, Arsenic in drinking water, Washington, DC: National Academy Press, 244, 2001.
30. C. W. Armstrong, R. B. Stroube, T. Rubio, Outbreak of fatal arsenic poisoning caused by contaminated drinking water, *Arch. Environ. Health* 39: 276-279, 1984.
31. SOES (School of Environmental Studies). November 1991. "Arsenic in groundwater of West Bengal: Bardhaman-The sixth districts affected (A preliminary study)", School of Environmental Studies & School of Water Resource Engineering, Jadavpur University, Kolkata - 700032, India.
32. S. K. Acharyya, S. Lahiri, B. C. Raymahashay, A. Bhowmik, Arsenic toxicity of ground water in parts of the Bengal basin in India and Bangladesh: the role of Quaternary stratigraphy and Holocene sea level fluctuation, *Environ. Geol.*, 39, 1127-1137, 1993.
33. S. K. Acharyya, P. Chakraborty, S. Lahiri, B. C. Raymahashay, S. Guha, A. Bhowmik, Arsenic poisoning in the Ganges delta, *Nature*, 401, 545-546, 1999.
34. S. Shankar, U. Shanker, Shikha, Arsenic Contamination of Groundwater: A Review of Sources, Prevalence, Health Risks, and Strategies for Mitigation, *The Scientific World Journal*, 2014:2014:304524, doi: 10.1155/2014/304524.
35. D. Marghade, G. Mehta, S. Shelare, G. Jadhav, K. C. Nikam, Arsenic Contamination in Indian Groundwater: From Origin to Mitigation Approaches for a Sustainable Future, *Water*, 15, 4125, 2023.
36. M. Madhukar, B. M. Sadashiva Murthy, T. H. Udayashankara, Sources of Arsenic in Groundwater and its Health Significance-A Review, *Nat. Env. & Poll. Tech.*, 15, 3, 971-979, 2016.
37. R. P. Borba, B. R. Figueiredo, J. Matschullat, Geochemical distribution of arsenic in waters, sediments and weathered gold mineralized rocks from Iron Quadrangle, Brazil, *Environmental Geology*, 44, 1, 39-52, 2003.





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38. L. Charlet, S. Chakraborty, C. A. J. Appelo, Chemodynamics of an arsenic “hotspot” in a West Bengal aquifer: a field and reactive transport modeling study, *Applied Geochemistry*, 22, 7, 1273-1292, 2007.
39. A. Biswas, S. Swain, N. R. Chowdhury, M. Joardar, A. Das, M. Mukherjee, T. Roychowdhury, Arsenic contamination in Kolkata metropolitan city: perspective of transportation of agricultural products from arsenic-endemic areas, *Environmental Science and Pollution Research*, 26, 22929-22944, 2019.
40. A. H. Welch, D. B. Westjohn, D. R. Helsel, R. B. Wanty, Arsenic in groundwater of the United States: occurrence and geochemistry, *Ground Water*, 38, 4, 589-604, 2000.
41. A. Malakar, B. Das, S. Islam, C. Meneghini, G. D. Giudici, M. Merlini, Y. V. Kolen'ko, A. Iadecola, G. Aquilanti, S. Acharya, S. Ray, Efficient artificial mineralization route to decontaminate Arsenic(III) polluted water-the Tooeleite Way, *Scientific Reports*, 6, 26031, 2016.
42. S. Alka, S. Shahir, N. Ibrahim, M. J. Ndejiko, D. N. Vo, F. A. Manan, Arsenic removal technologies and future trends: A mini review, *Journal of Cleaner Production*, 278, 1, 123805, 2021.
43. R. Dutta, P. Bose, P. Ghosh, Arsenate recognition in aqueous media by a simple tripodal urea, *Dalton Trans.*, 42, 11371-11374, 2013.
44. C. D. Moffat, D. J. Weiss, A. Shivalingam, A. J. P. White, P. Salaun, R. Vilar, Molecular Recognition and Scavenging of Arsenate from Aqueous Solution Using Dimetallic Receptors, *Chem. Eur. J.*, 20, 17168-17177, 2014.
45. H. R. Hassan, A review on different arsenic removal techniques used for decontamination of drinking water, *Environmental Pollutants and Bioavailability*, 35, 1, 2165964, 2023.
46. Y. Wang, L. Zhang, C. Guo, Y. Gao, S. Pan, Y. Liu, X. Li, Y. Wang, Arsenic removal performance and mechanism from water on iron hydroxide nanopetalines, *Scientific Reports*, 12, 17264, 2022.
47. P. Mahamallik, R. Swain, A mini-review on arsenic remediation techniques from water and future trends, *Water Science & Technology*, 87,12, 3108, 2023.
48. R. S. Neisan, N. M. C. Saady, C. Bazan, S. Zendehboudi, A. Al-nayili, B. Abbassi, P. Chatterjee, Arsenic Removal by Adsorbents from Water for Small Communities' Decentralized Systems: Performance, Characterization, and Effective Parameters, *Clean Technol.*, 5, 352-402, 2023.
49. O. X. Leupin, S. J. Hug, Oxidation and removal of arsenic (III) from aerated groundwater by filtration through sand and zero-valent iron, *Water Research*, 39, 9, 1729-1740, 2005.
50. Y. Lee, I.-H. Um, and J. Yoon, “Arsenic (III) oxidation by iron(VI) (ferrate) and subsequent removal of arsenic (V) by iron (III) coagulation,” *Environmental Science and Technology*, 37, 24, 5750-5756, 2003.
51. M. C. Dodd, N. D. Vu, A. Ammann, Kinetics and mechanistic aspects of As(III) oxidation by aqueous chlorine, chloramines, and ozone: relevance to drinking water treatment, *Environmental Science and Technology*, 40,10, 3285-3292, 2006.
52. S. Bajpai, M. Chaudhuri, Removal of arsenic from ground water by manganese dioxide-coated sand, *Journal of Environmental Engineering*, 125, 8, 782-784, 1999.
53. L. S. McNeill, M. Edwards, Soluble arsenic removal at water treatment plants, *Journal of American Water Works Association*, 87, 4, 105-113, 1995.
54. V. Pallier, G. F. Cathalifaud, B. Serpaud, J. C. Bollinger, Effect of organic matter on arsenic removal during coagulation/flocculation treatment, *Journal of Colloid and Interface Science*, 342, 1, 26-32, 2010.
55. C. Hu, H. Liu, G. Chen, and J. Qu, Effect of aluminum speciation on arsenic removal during coagulation process, *Separation and Purification Technology*, 86, 35-40, 2012.
56. D. Mohan, C. U. Pittman Jr., Arsenic removal from water/wastewater using adsorbents - a critical review, *Journal of Hazardous Materials*, 142, 1-2, 1-53, 2007.
57. S. Sarkar, L. M. Blaney, A. Gupta, Use of ArsenXnp, a hybrid anion exchanger, for arsenic removal in remote villages in the Indian subcontinent, *React Funct Polym.*, 67(12), 1599-1611, 2007.
58. M. K. Ghosh, G. E. J. Poinern, T. B. Issa, Arsenic adsorption on goethite nanoparticles produced through hydrazine sulfate assisted synthesis method, *Korean J Chem Eng.*, 29(1), 95-102, 2012.
59. R. Jain, Recent advances of magnetite nanomaterials to remove arsenic from water, *RSC Adv.*, 12(50): 32197-32209, 2022.
60. T. A. Siddique, N. K. Dutta, N. R. Choudhury, Nanofiltration for Arsenic Removal: Challenges, Recent Developments, and Perspectives, *Nanomaterials*, 10(7), 1323, 2020.





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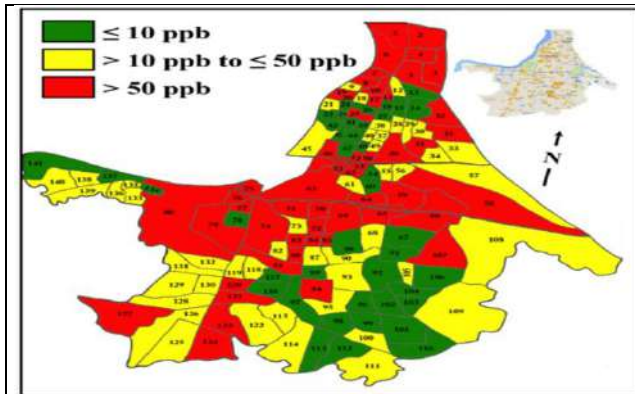


Fig. 1: West Bengal map showing arsenic contamination as per PHE report [13].

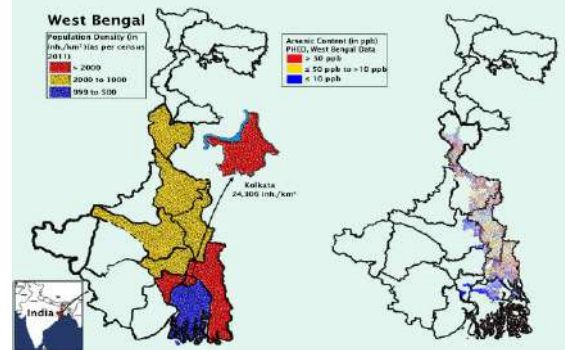


Fig. 2: Arsenic contamination of Kolkata Municipal Corporation ward-wise [13].

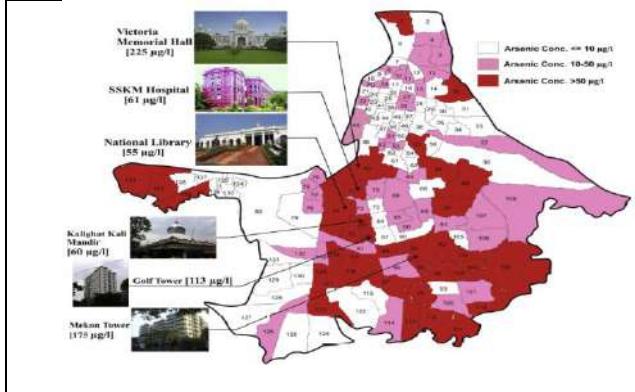


Fig. 3: Arsenic contamination in some important areas in KMC [14].



Fig. 4: Different types of Disease due to arsenic toxicity (SOES, Jadavpur University, Kolkata) [31].





Formulation and Evaluation of Chewable Tablets using *Hingwashtak churna*

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ABSTRACT

A common approach to addressing digestive system issues involves integrating herbal preparations into one's diet, which can enhance digestive function. Among the various dosage forms available for delivering active substances such as pharmaceuticals, nutraceuticals, and veterinary products, chewable tablets stand out due to their ease of use, accurate dosing, portability, and extended shelf life. One notable Ayurvedic formulation in powder form, rich in phytochemicals like alkaloids, glucosides, tannins, and phenols, is *Hingwashtak Churna*. Comprising eight key ingredients—*Cuminum cyminum*, *Ferula foetida*, *Zingiber officinale*, *Piper nigrum*, *Piper longum*, *Nigella sativa*, *Trachyspermum ammi*, and *Saindhava Lavana* (rock salt)—this blend is known for its digestive benefits. In a recent study, chewable tablets containing *Hingwashtak Churna* were formulated and evaluated using a direct compression method. The ingredients—Long pepper, Pepper, White Cumin, Black cumin, Awain, Asafoetida, Himalaya pink salt (*Saindhava lavanam*), Dry ginger (Sonthi), and the standard *Hingwashtak Churna*—were procured from the market and utilized in the preparation. Evaluation parameters included hardness, friability, and weight variation. The results indicated favorable characteristics for the formulated chewable tablets: a measured angle of repose of 40.090, compressibility index of 18, and Hausner's ratio of 1.21, whereas the marketed product showed 350, 13.33, and 1.15, respectively. Additionally, the weight variation, hardness, and friability of the prepared product were found to be 99.06%, 0.02, and 1.8, respectively, compared to 99.3%, 0.06, and 0.8 for the marketed product. Overall, chewable tablets formulated with the prepared active pharmaceutical ingredient (API) demonstrated superior performance in comparison to those using the marketed API, suggesting the potential efficacy of this approach in enhancing digestive health.





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Keywords: *Hingwashtak Churna*, Digestive disorders, chewable tablets, Ayurvedic formulation, Direct compression

INTRODUCTION

Herbal medicine has made substantial contributions to human health due to its capacity for health promotion, curative properties, and rehabilitation capabilities. Herbal medicine, often referred to as botanical medicine, phytomedicine, or phytotherapy, encompasses a wide range of components, preparations, and products derived from plants that contain biologically active compounds [1]. Numerous studies indicate that across the globe, traditional practices of using herbal preparations to alleviate digestive system disorders are widespread. These herbal preparations play a crucial role in enhancing digestive system function. They operate in various ways, such as healing the intestinal lining, facilitating digestion, promoting regular bowel movements, aiding detoxification, eliminating toxins, soothing upset stomachs, and reducing gas, bloating, and digestive discomfort [2-5]. *Hingwashtak Churna* is a renowned polyherbal Ayurvedic blend available in powder form, comprising eight primary ingredients: *C. cyminum*, *F. foetida*, *Z. officinale*, *P. nigrum*, *P. longum*, *N.sativa*, *T. ammi*, and *Saindhava Lavana* (rock salt). This preparation, recognized by herbal pharmacopoeia and Ayurvedic Formulary of India, encompasses a synergistic combination where each component plays a distinct role. The presence of phytochemicals such as alkaloids, glycosides, tannins, and phenols further enhances its therapeutic potential.

Medicinal uses of *Hingwashtak Churna*

The pharmacological actions of *Hingwashtak Churna*⁶ encompass its role as a polyherbal formulation aiding digestion and treating digestive disorders. Recognized as a carminative and antispasmodic, it offers relief in various gastrointestinal conditions. Comprising mainly eight ingredients, each component serves distinct therapeutic purposes. Rock salt aids digestion, while ginger powder targets indigestion. Black pepper and long pepper act as carminatives, and asafoetida along with cumin address digestive problems like flatulence. Carom seeds and cumin stimulate gastric acid secretion, further aiding digestion.

Benefits of *Hingwashtak Churna*

P. nigrum and *P. longum* exhibit carminative activity, easing gastrointestinal flatulence. Asafoetida contributes to reducing flatulence and abdominal distension. *Hingwashtak Churna* also proves effective in alleviating abdominal pain associated with primary dysmenorrhea, regulating menstrual cycles, and easing menstrual flow. Ginger powder, a constituent of *Hingwashtak Churna*, aids in treating indigestion by reducing food retention time, enhancing bile acid secretion, and improving the efficacy of digestive enzymes. Studies indicate that the aqueous extract of *Hingwashtak Churna* reduces gastric ulcer size, attributed to the antioxidant activity of its ingredients. This suggests its potential as an adjunct to existing peptic ulcer treatments [7-9].

MATERIALS AND METHODS

Preparation of *Hingwashtak Churna*

Prepared product

- Long pepper, Pepper, White Cumin, Black cumin, Ajwain, Asafoetida, Himalaya pink salt (*Saindhava lavanam*), Dry ginger (Sonthi) were procured from the market.
- All the ingredients were ground into a fine powder.
- 10 g of API is prepared by,

Preparation of chewable tablets

Chewable tablets (each 600 mg) were prepared by Direct compression method using the below formulation¹⁰,





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Prepared/ Marketed *Hingwashtak Churna*

RESULTS AND DISCUSSION

Physico-chemical properties of chewable tablets made of *Hingwashtak Churna* prepared and marketed product were evaluated [Table 4a&b]. The analysis of chewable tablets showed satisfactory results [Table 5, 6]. PRE & POSTCOMPRESSION STUDIES

CONCLUSION

In ayurveda, *Hingwashtak Churna* is administered in powder form which is difficult to administer. Hence in this research it is aimed to prepare chewable tablets by using prepared *Hingwashtak Churna* and marketed product. Chewable tablets made by using Prepared product revealed promising results, with favorable characteristics such as hardness, friability, and weight variation. The organoleptic characteristics of *Hingwashtak Churna* chewable tablets include a sweet taste, achieved by the addition of a sweetening agent to enhance palatability. These tablets exhibit a light brown color, making them suitable for consumption by elderly and diabetic individuals, as stevia, a natural sweetening agent, is used. Regarding their physical properties, chewable tablets formulated with prepared *Hingwashtak Churna* demonstrate a hardness of 1.8, ensuring they can be chewed without difficulty. With a friability of 0.02%, these tablets are sturdy yet easily portable, minimizing breakage during handling. Their disintegration time of 15-20 minutes allows for effortless dissolution in the mouth. Additionally, the weight variation of \pm % facilitates precise dosing, ensuring the delivery of the therapeutic dose. The formulation of chewable tablets offers advantages over traditional powder and conventional tablet dosage forms, effectively addressing associated disadvantages.

REFERENCES

1. Philomena G. Concerns regarding the safety and toxicity of medicinal plants - An overview. *J Appl Pharmaceut Sci.* 2011;1(6):40–4.
2. Nasri H. Cisplatin therapy and the problem of gender-related nephrotoxicity. *J Nephroarmacol.* 2013;2(2):13–4.
3. Haq I. Safety of medicinal plants. *Pak J Med Res.* 2004;43(4):203–10.
4. Nasri H. Renoprotective effects of garlic. *J Renal Inj Prev.* 2012;2(1):27–8.
5. Kazemipoor M, Radzi CW, Cordell GA, Yaze I. Safety, efficacy and metabolism of traditional medicinal plants in the management of obesity: a review. *Int J Chem Eng Appl.* 2012;3(4):288–92.
6. Pal RS, Pal Y, Wal P, Wal A. In house & Marketed Preparation of *Hingwashtak Churna*, A Polyherbal Formulation: Comparative Standardization and Measures. *Open Medicine Journal.* 2018 Nov 1;5(1):76–83. Available from: <https://www.semanticscholar.org/paper/In-house-%26-Marketed-Preparation-of-Hingwashtak-A-Pal-Pal/0459b545a2a70b254e6041d4cbac3fe818b6e1cd>
7. Ajay Patil V, Hemantrao Zadbuke D, Pundalikrao Deshmukh S. AYURVEDIC MANAGEMENT OF DYSMENORRHOEA. *World Journal of Pharmaceutical Research* [Internet]. 2019;8:1200. Available from: www.wjpr.net
8. Shirwaikar A, Ram HNA, Mohapatra P. Antioxidant and antiulcer activity of aqueous extract of a polyherbal formulation. *IJEB Vol44(06)* [June 2006] [Internet]. 2006 [cited 2022 Feb 16];44:474–80. Available from: <http://nopr.niscair.res.in/handle/123456789/6522>
9. The ayurvedic formulary of India. Ayurvedic Pharmacopoeia Committee. Ministry of Health and Family Welfare. Government of India. 2000. Available from: https://books.google.com/books/about/The_Ayurvedic_Formulary_of_India.html?id=H6FFAAAYAAJ
10. LACHMAN, L., LIEBERMAN, H. A., & KANIG, J. L. (1976). *The theory and practice of industrial pharmacy.* Philadelphia, Lea & Febiger.





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Table 1: Composition of Hingwashtak Churna

S.NO.	INGREDIENTS	
	Biological Name	Common Name
1.	<i>C. cyminum</i>	Cumin
2.	<i>F. foetida</i>	Asafoetida
3.	<i>Z. officinale</i>	Ginger
4.	<i>P. nigrum</i>	Black pepper
5.	<i>P. longum</i>	Long pepper
6.	<i>N. sativa</i>	Fennel
7.	<i>T.ammi</i>	Carom seed/Ajwain
8.	<i>Saindhava lavana</i>	Rock salt

Table 2: Composition of Prepared Product

S.NO.	INGREDIENT	QUANTITY
1.	Long Pepper	1.4 g
2.	Pepper	1.4 g
3.	White Cumin	1.4 g
4.	Black Cumin	1.4 g
5.	Ajwain	1.4 g
6.	Dry Ginger	1.4 g
7.	Saindhava Lavanam	1.4 g
8.	Asafoetida	200 mg

Table 3: Composition of Chewable Tablets (Prepared)

S.NO.	INGREDIENTS	QUANTITY
1.	API [†]	200 mg
2.	Acacia	100 mg
3.	Micro Crystalline Cellulose (MCC)	280 mg
4.	Magnesium Stearate	5 mg
5.	Talc	5 mg
6.	Stevia	10 mg

Table 4 a) : Organoleptic evaluation of Hingwashtak Churna

S.NO.	PARAMETERS	PREPARED PRODUCT	MARKETED PRODUCT
1.	Colour	Dark Brown	Pale Yellow
2.	Odour	Characteristic	Characteristic
3.	Taste	Pungent	Pungent
4.	Appearance	Powder	Powder

Table 4b): Loss on Drying

TEST	PREPARED PRODUCT	MARKETED PRODUCT
Loss on Drying	10 %	12%



**Gana Manjusha et al.,****Tablet 5: Pre compression Parameters**

S.NO.	TEST	PREPARED PRODUCT	MARKETED PRODUCT
1.	Angle of Repose	35°	40.09°
2.	Bulk density	0.39 g/mL	0.41 g/mL
3.	Tapped density	0.45 g/mL	0.5 g/mL
4.	Compressibility index	13.33 %	18 %
5.	Hausner Ratio	1.15	1.21

Tablet 6: Post compression Parameters

S.NO.	TEST	PREPARED PRODUCT	MARKETED PRODUCT
1.	Weight Variation	99.6	99.3
2.	Friability	0.02	0.06
3.	Hardness	1.8	0.8





Validation of Quality Parameters of Siddha Formulation "Vatharatchasan Mathirai"

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ABSTRACT

Vatha Ratchasan Mathirai (VRM) *Vatha Ratchasan Mathirai* is a commonly prescribed herbo-metallic compound drug mainly composed of mercurial compounds ground with herbal juices. The qualities of stability over an extended period, decreased dosage requirements, ease of storage, and prolonged availability are the benefits of herbo-metallic preparation over herbal medications. During the purifying and preparing processes, treating metals and minerals with herbs transforms them into forms that are substantially more bio-compatible, even though they are thought to have less bioavailability. Assessment of quality parameters is necessary to confirm the identity and evaluate the purity of the medicine. We must investigate the medicine quality for human use using data supporting their efficacy and safety. For this reason, quality assessment is crucial to future preclinical and clinical research. So quality of VRM is analyzed. The Study results conclude *Vatha Ratchasan Mathirai* is solid dark black in colour, uniformity in weight, disintegrate within 20 minutes, free from pesticides residues, aflatoxins, microbial contamination and heavy metals.

Keywords: Osteoarthritis, Physico-chemical analysis, Qualitative assessment, Siddha Medicine, *Vatha ratchasan Mathirai*.





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INTRODUCTION

Osteoarthritis (OA) is a chronic joint bone disease characterized by inflammatory destruction and hyperplasia of bone [1]. The prevalence of OA in India according to 2019 is 62.35 million [2]. There is currently no known treatment for Osteoarthritis (OA) because the pathological process behind the onset of the disease and its progression is not fully understood. To create therapeutic targets and develop new drugs, a deeper comprehension of the pathogenic signaling pathways and important molecules implicated in the pathogenesis of OA is essential.[1]The application of herbs, metals, and minerals among the wealth of therapeutic knowledge that the Siddha system has amassed. The practitioners of the Siddha medical system referred to as *Siddhars*, are exceptional entities possessing advanced cultural and intellectual capacities.[3]To change the vitiated humor, *Siddhars* blends formulas based on complementary and antagonistic tastes, due to which they produce higher efficacy with less toxicity. When it comes to treating non-communicable diseases in clinical settings, Siddha formulations are incredibly advantageous.[4] Research on Siddha formulations is often conducted using a reverse pharmacology approach. *Vatha Ratchasan Mathirai*[5] is a Herbo-metallic medicine that has been used for millennia to cure a variety of conditions, including polio, chronic arthritis, delirium, and diseases resulting from vitiated humour.[6] Due to a clear grasp of the mechanism through research, rising popularity and long-term stability have raised the current demand for Siddha formulations globally.[7] Recently, there has been interest both domestically and globally in the commercialization of Siddha medicine manufacturing. Siddha formulations now require quality control, safety, and crucial standardization. To support globalization, it is imperative that these ideas be presented, comprehended, and incorporated more precisely into Siddha formulations. As a result, the manufacturing of high-quality, safe, effective, and standard medications must be the top priority for Siddha drug processing units.[8] A quality analysis of *Vatha Ratchasan Mathirai* is necessary to demonstrate the purity and excellence of the drug. Physiochemical, microbiological, pesticide residue, aflatoxin, and heavy metal analysis are the main methods used to accomplish this under the Protocol for Testing of Parameters for Quality Assessment of Ayurvedic and Siddha Medicines.[9]

MATERIALS AND METHODS

The medicine was purchased from IMPCOPS, Chennai. Heavy metals and physiochemical analysis were performed at SCRI, Arumbakkam, Chennai 600 106. On the premises of the Asthagiri Herbal Research Foundation, Perungudi, Chennai 600 096, microbiological contamination was conducted. Furthermore, tests for aflatoxin and pesticide residue were conducted at Noble Research Solutions, an ISO 9001-2015 accredited business located in Chennai.

PHYSICOCHEMICAL ANALYSIS

Determination of Moisture Content (Loss on Drying)

Without prior drying, 10 gm of the medicine was correctly weighed in a tared evaporating dish, dried at 105°C for 5 hours, chilled in desiccators, and weighed. Subsequently, the drying and weighing procedure was repeated every hour until the discrepancy between the initial and two subsequent weightings did not exceed 0.25 percent. The percentage of moisture content was computed using the air-dried drug as a reference once the constant weight was determined.[10]

Uniformity of weight

Calculate the average sample weight by weighing each of the twenty randomly chosen sample units separately.[11]

Disintegration Test

Five tablets (80–100 mm/μg) were placed in the glass tube and the guided disc was used to raise and lower the tube 30 times in a minute. When there are no more particles above the gauze that are difficult to pass through, the tablets have broken down. Then the time for disintegration of the tablet was calculated.[11]



**Prathisha et al.,****Hardness Test**

Two tests were used to perform the hardness test: the point bend test and the compression test. The tablet was squeezed between a stationary and moving jaw during the compression test. The original machines used a spring and screw threads to apply force continuously until the tablet began to shatter. A sliding scale was used to determine the hardness when the tablet broke.[11]

Determination of Total Ash

In a tared platinum or silica dish, 2-3g precisely weighted drug was incinerated at not more than 450°C till it was carbon-free, then cooled and weighed. Calculate the percentage of ash reference to the air-dried drug.[10]

Determination of Acid Insoluble Ash

The insoluble materials were collected on ash-less filter paper, boil the ash acquired in the total ash technique for five minutes with 25 milliliters of diluted HCL, washed with hot water, and ignited to constant weight. The percentage of acid insoluble ash was calculated.[10]

Determination of Alcohol and soluble extractive

Five grams of drug powder were macerated in 100 milliliters of water for six hours, shaking constantly, and then placed in a conical flask with a glass stopper and allowed to stand for the next eighteen hours. After that, the filtrate was rapidly collected using a dry filter. A flat-bottom Petri plate that had been weighed, tar-coated, and water-bathed was used to hold 25 milliliters of the filtrate. The remaining material was dried for six hours at 105°C and desiccated for thirty minutes before being weighed. The percentage of water-soluble components was calculated in relation to the medicine dosage. As previously noted, alcohol was substituted for water to determine the proportion of alcohol-soluble material.[10]

Determination of pH

Using a standard glass electrode set at 240 degrees Celsius, the pH of various formulations in 1% w/V and 10% w/V of water-soluble fractions was measured in conformity with the recommended standard procedure mentioned in Indian pharmacopeia.[11]

MICROBIAL CONTAMINATION ANALYSIS**Objective**

The pour plate techniques were adopted to determine the sterility of the product. Contaminated/unsterile sample (formulation) when encounter the nutrition-rich medium it promotes the growth of the organism and after a stipulated period of incubation the growth of the organism was identified by a characteristic pattern of colonies. The colonies are referred to as Colony Forming Units (CFUs).[12]

Methodology

The test sample was admixed with sterile distilled water and the mixture has been used for the sterility evaluation. About 1 ml of the test sample was inoculated in a sterile petri dish to which about 15 ml of molten agar 45°C was added. Agar and sample were mixed thoroughly by tilting and swirling the dish. Agar was allowed to completely gel without disturbing it. (About 10 minutes). Plates were then inverted and incubated at 37° C for 24-48 hours and further extended for 72 hrs for fungal growth observation. Grown colonies of organism was then counted and calculated for CFU.[12]

TEST FOR AFLATOXINS**Procedure**

Standard Aflatoxin was applied onto the surface to pre coated TLC plate in the volume of 2.5 µl, 5 µL, 7.5 µl and 10 µL. Similarly, the test sample was placed and allow the spots to dry and develop the chromatogram in an



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unsaturated chamber containing a solvent system consisting of a mixture of chloroform, acetone, and isopropyl alcohol (85:10:5) until the solvent front has moved not less than 15 cm from the origin. Remove the plate from the developing chamber, mark the solvent front and allow the plate to air-dry. Locate the spots on the plate by examination under UV light at 365 nm.[13]

PESTICIDE RESIDUE

Determination of pesticide residues for analysis reagents without any external components was chosen and the samples were analyzed using Gas chromatographic methods. Later the number of different components such as organophosphorus, organochlorine and pyrethroid contents was recorded.[14]

HEAVY METAL ANALYSIS BY ICP-OES METHOD**Standard**

Hg, As, Pb, and Cd

Methodology

100 mg of sample was taken in the Teflon microwave digestion vessel and 1.0 mL of ultrapure nitric acid was added and digested for 45 minutes in a closed vessel microwave digestion unit. Then the sample was made up to 50 ml in a standard measuring flask. The calibration standard was prepared to elucidate the linearity of the analytic ranging from 0.25µg/ml to 10.0 µg/ml. Agilent 5100 VDV ICP-OES instrument was used with the following operation conditions: View: Axial view, RF powder: 1.2 kW, Plasma gas flow rate: 12L min⁻¹, and nebulizer gas flow rate: 0.70 L min⁻¹. The samples are introduced into the plasma using a nebulizer and spray chamber.[15]

RESULTS

Standardization of the drug is essential to derive the efficacy and potency of the drug which was analyzed by various methods. The results of organoleptic characters (Table No: 1), physicochemical analysis (Table No: 2), Microbial contamination (Table No: 3), Aflatoxin (Table No: 4), Pesticide residue (Table No: 5), and Heavy metal analysis (Table No: 6) of VR is tabulated below.

DISCUSSION

The loss on drying at 105°C was found to be 0.75% which indicated less moisture content in *VRM* thus preventing it from early spoilage. Loss on drying assesses both moisture and volatile matter in *VRM*. Their low moisture and volatile matter levels curb microbial growth, fungal or insect presence, and hydrolysis-related degradation. Thus, the drug has a higher shelf-life. pH is 5.35 determining the nature of the drug to be acidic. The acidic nature of the drug enables its absorption in the stomach. It demonstrates that *VRM* is appropriate and readily absorbed when taken orally. The higher total ash value compared to the acid insoluble ash values could be attributed to naturally occurring adhered inorganic salts. The total ash (43.52%w/w) shows the total inorganic components in the drug. Acid insoluble ash (13.15%w/w) is more than 1% indicating siliceous material i.e., inorganic components such as Si, Bo. The extractive values indicate the presence of both polar and non-polar components. Water soluble extractive & Alcohol soluble Extractive were found to be 10.75%w/w and 9.35%w/w The value of water-soluble extractive is higher showing the presence of carboxylic acids tannins, sugars, and phytoconstituents. The value of Alcohol soluble extractive is 9.35% indicating the presence of alkaloids. [16,17] A collection of substances used to eradicate pests that pose a threat to domesticated plants is known as a pesticide. The pesticides leave behind residue that is harmful for consumption. The presence of pesticide residue is essential to be evaluated for safe consumption in humans. The results of *VRM* showed that it is free from pesticide residue. [18] Aflatoxin is a naturally occurring mycotoxin produced by *Aspergillus parasitica* and *Aspergillus Flavus*. In medicines composed of herbs, it is necessary to assess the presence of aflatoxin to prevent toxicity. Thus, reliable, and sensitive aflatoxin detection typically requires elaborate





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procedures and a powerful detection device. By using TLC plates the formulation VRM is studied for aflatoxin and found to be free from Aflatoxin.[19] One of the most significant safety issues associated with herbo-mineral medicines is contamination by bacteria of various types that may be adherent to the herbs from which medicine is manufactured. VRM is free from microbial contamination. [20] The heavy metal analysis showed **Pb**, **Cd**, and **As** were below the detection level but **Hg** is 0.53ppm which is under the AYUSH permissible limit. The detectable level of Hg is due to the presence of mercury as one of the ingredients in the formulation. [20]

CONCLUSION

From the results, it is concluded Vatha Ratchasan Mathira is safe for consumption since it is free from aflatoxin, heavy metals, and microbial contamination. Also, the Physicochemical evaluation shows the purity, integrity, and safety of the drug. Furthermore, research studies must be carried out to assess the toxicity and efficacy of *VathaRatchasan Mathirai*.

REFERENCES

1. Du, X., Liu, Z.-y., Tao, X.-x., Mei, Y.-l., Zhou, D.-q., Cheng, K., Gao, S.-l., Shi, H.-y., Song, C. and Zhang, X.-m. (2023), Research Progress on the Pathogenesis of Knee Osteoarthritis. *Ortho Surg*, 15: 2213-2224. <https://doi.org/10.1111/os.13809>
2. Singh A, Das S, Chopra A, Danda D, Paul BJ, March L, Mathew AJ, Shenoy P, Gotay C, Palmer AJ, Antony B. Burden of osteoarthritis in India and its states, 1990-2019: findings from the Global Burden of disease study 2019. *Osteoarthritis Cartilage*. 2022 Aug;30(8):1070-1078. doi: 10.1016/j.joca.2022.05.004. Epub 2022 May 19. PMID: 35598766.
3. Standardization of Siddha Herbo mineral formulation "linga mathirai" Shanuvass A*, Indhumathi M Department of Gunapadam, Government Siddha Medical College, Arumbakkam, Chennai, Tamil Nadu. Email: dr.shanuvass@gmail.com Received: 09 February 2017, Revised and Accepted: 27 March 2018 *Asian journal of pharmaceutical and clinical research*
4. Dr.R. Thiyagarajan, Gunapadam Thathu-Seevavaguppu, Indian Medicine-Homeopathy Department, Chennai-106, 8th Edition- 2013, page.no:56, 57, 128, 129, 144, 145, 150, 160, 161, 225-234, 239-243, 302-304, 515, 516, 518,
5. Agathiyar vaiithiya rathna surukkam, Published by Thamarai Noolagam Chennai-26, page.no:12,13.
6. K.N. Kuppusswamy Mudhaliyar (Ed.), Siddha Vaidhiya Thirattu (1st ed.), Chennai, Tamil Nadu, Department of Indian Medicine, and Homoeopathy, 1998.
7. C.R. Sreedhana and M. Mohammed Mustafa, Formulation, standardization, and Physiochemical evaluation of Novel Siddha Preparation Naga Chenduram as per AYUSH guideline, *International Journal of Advanced Research in Biological Sciences*, 2017, Vol: 4(11):16-21.
8. Ponnappan, Shanmugapriya. (2016). Toxicological Profiling of Santha Santhrodhaya Mathirai (SSM) A Siddha Herbo mineral Formulation in Rats. Shanmugapriya P, Murugesan M2 1Lecturer, Department of Nanju noolum Maruthuva Neethi Noolum, National Institute of Siddha, Chennai, India 2Former Dean, National Institute of Siddha, Chennai, India. *IOSR Journal of Dental and Medical Sciences (IOSR-JDMS)*. Volume 15, Issue. PP 01-08. 10.9790/0853-1504120108.
9. Pharmacopoeial Laboratory for Indian Medicine (PLIM) Guideline for standardization and evaluation of Indian medicine which includes drugs of Ayurveda, Unani, and Siddha systems. Department AYUSH. Ministry of Health & Family Welfare, Govt. of India
10. Suraj J. Patil, Shivani D. Patil, Pratibha B. Patil, Pranali S. Patil, Ganesh B. Vambhurkar, Indryani D. Raut. Evaluation of Standardization Parameters of Ayurvedic Marketed Polyherbal Formulation. *Asian J. Pharm. Ana*. 2018; 8(4): 220-226.
11. Shunmugaram S. Physicochemical and Acute Toxicity Analysis of a Siddha Herbo-Mineral Formulation – Pachai Karpoora Vadagam (PKV). *Research J. Pharm. and Tech* 2019; 12(1): 227-230.





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12. R, S., and A. N. "Analysis of Heavy Metal, Aflatoxin, Pesticide Residue and Microbial Contamination of Siddha Herbal Formulation Muppirandai Chooranam." *World Journal of Current Medical and Pharmaceutical Research*, Vol. 5, no. 5, Sept. 2023, pp. 163-7, doi:10.37022/wjcmpr. v5i5.286.
13. Luciana de CASTRO. Determining Aflatoxins B1, B2, G1 and G2 in Maize Using Florisil Clean Up with Thin Layer Chromatography and Visual and Densitometric Quantification. *Ciênc. Tecnol. Aliment.* vol.21 no.1 Campinas. 2001.
14. Jayabarathi J, Amaravathi S, Menaka R, Chitra U, Anbu N. SYSTEMATIC STANDARDIZATION OF NOVEL SIDDHA FORMULATION PASUNEER KADUKKAI CHOORANAM BY MODERN ANALYTICAL TECHNIQUES. *Int J Trans Res Ind Med.* 2023;5(2):16-22.
15. M JV, Abdul Kader Jeylani MP. Muthu Parpam- Heavy Metal Analysis by ICP-OES. *jtim* [Internet]. 2022]Jun.16 [cited 2024Feb.23];5(2):473-6. Available from: <http://jtim.biosci.in/ojs/index.php/jtim/article/view/111>
16. Hapuarachchi, S., Silva, D., Kodithuwakku, N., & Perera, K, Evaluation of phytochemical, physicochemical parameters and HPTLC fingerprints of different extracts of Nil Aweriya (*Indigofera tinctoria* L.) leaves grown in Sri Lanka, *Asian J. Pharmacogn*,2020, 4(4): 22-3.
17. Indian Pharmacopeia, Volume I, 2018,7, 208,140,141,329,215-216.
18. Lee SH, Kim HS, Kim YM, Kim WS, Won YJ, Chae GY, Kim OH, Park HJ, Jeong SW. Monitoring of pesticide residues in herbal medicines. *Journal of Environmental Science International.* 2006;15(8):811-7.
19. Victor Jeyaraj SV, Loy MJ, Goh KW, Lean YL, Chan SY, Ming LC. Aflatoxin tests in herbal products and its quantification: Latest updates. *Front Nutr.* 2022 Sep 8; 9:956077. doi: 10.3389/fnut.2022.956077. PMID: 36159500; PMCID: PMC9493432.
20. Zamir, R., Hosen, A., Ullah, M. O., & Nahar, N. (2015). Microbial and Heavy Metal Contaminant of Antidiabetic Herbal Preparations Formulated in Bangladesh. *Evidence-Based Complementary and Alternative Medicine*, 2015, 1–9. doi:10.1155/2015/243593

Table: 1-Organoleptic Characters of *Vatha Ratchasan Mathirai*

PARAMETERS	RESULTS
State	Solid
Appearance	Dark black
Odour	Mild Aromatic
Nature	Soft tablet

Table: 2-Physicochemical properties of *Vatha Ratchasan Mathirai*

PARAMETER	RESULT
Loss on drying	0.75 %
Uniformity of weight	0.102g (Average weight) none deviates beyond permissible limit
Disintegration Time	All disintegrated with 20 minutes
Hardness	Withstands up to 2.3kg
Total Ash content	43.52%
Acid insoluble Ash	13.15%
Water soluble Extraction	10.75%
Alcohol soluble Extraction	9.35%
pH (10% of solution)	5.35%





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Table: 3-Microbial Contamination Test of Vatha Ratchasan Mathirai

S. No	Parameters	Results (CFU)
1.	Total Bacterial Content	Nil (10^6)
2.	Total Fungal Content	Nil (10^3)

Table: 4-Aflatoxin Analysis of Vatha Ratchasan Mathirai

Aflatoxin	Sample	AYUSH Specification Limit
B ₁	Not Detected	0.5 ppm
B ₂	Not Detected	0.1 ppm
G ₁	Not Detected	0.5 ppm
G ₂	Not Detected	0.1 ppm

Table: 5- Pesticide Residue Analysis of Vatha Ratchasan Mathirai

S. No	Parameters	Sample	AYUSH Limit mg/kg
Organo Chlorine Pesticides			
1.	Alpha BHC	BQL	0.1mg/kg
2.	Beta BHC	BQL	0.1mg/kg
3.	Gamma BHC	BQL	0.1mg/kg
4.	Delta BHC	BQL	0.1mg/kg
5.	DDT	BQL	1mg/kg
6.	Endosulfan	BQL	3mg/kg
Organo Phosphorus pesticides			
7.	Malathion	BQL	1mg/kg
8.	Chlorpyrifos	BQL	0.2mg/kg
9.	Dichlorovos	BQL	1mg/kg
Organo carbamates			
10.	Carbofuran	BQL	0.1mg/kg
Pyrethroid			
11.	Cypermethrin	BQL	1mg/kg

BQL - Below Quantifiable Limit, DL -Detection Limit.

Table: 6-Heavy Metal Analysis of Vatha Ratchasan Mathirai

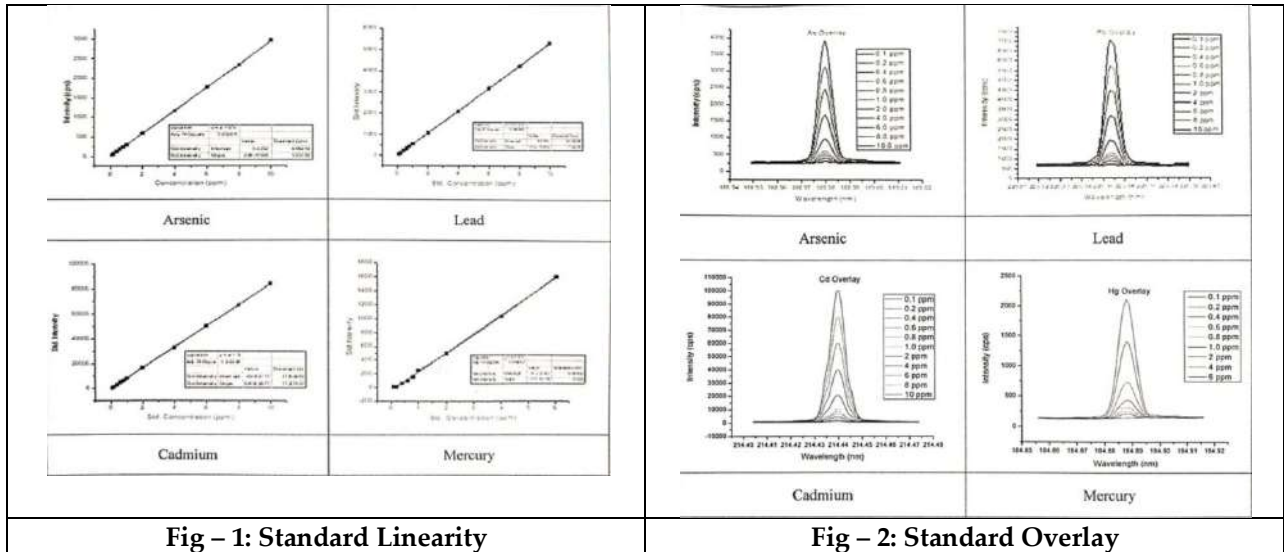
Elements	Max. Absorption	Result	Max. Limit
Arsenic (As)	193.7 nm	BDL	3 ppm
Mercury (Hg)	253.7 nm	0.53	1 ppm
Cadmium (Cd)	228.8 nm	BDL	0.3 ppm
Lead (Pb)	217 nm	BDL	10 ppm

BDL – Below Detection Limit





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Identifying Prenatal, Perinatal and Neonatal Risk Factors Influencing on NICU (Neonatal Intensive Care Unit) Stay Duration

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ABSTRACT

The neonatal intensive care unit (NICU) serves as a crucial environment for the care and treatment of newborns who require specialized medical attention due to various health challenges. The duration of stay in the NICU is a critical parameter that reflects the complexity of the neonate's health condition and the effectiveness of medical interventions. aim and objective of this study is to identify prenatal, perinatal, and neonatal risk factors for influencing long duration in NICU stay of newborns and to provide a basis for interventions to shorten NICU stay duration and factors affecting their hospitalization duration to lessen unwanted outcomes of infants and to eliminate or relieve the problems. The data collection phase involved gathering information from various paediatric hospitals, particularly those equipped with Neonatal Intensive Care Units (NICUs), across different zones in Surat. based on selection, criteria Infants were assessed for risk factors and NICU stay duration as per assessment form assessment form includes patient's demographic data, prenatal, perinatal, neonatal history, family history From this study it has been identified that prenatal maternal seizure, gestational diabetes, IVF Pregnancy, maternal medication and oligohydramnios, Perinatal-Birth weight, Prematurity and birth asphyxia and neonatal-Neonatal seizures, Low Apgar score, Neonatal hypoglycemia and respiratory distress syndrome shows significant association with NICU stay duration. In conclusion, we identified several of the most critical risk factors affecting increase NICU stay duration

Keywords: Prenatal, Perinatal and neonatal risk factors , NICU stay duration





Pranali Thakkar and Madhavan Iyengar

INTRODUCTION

The neonatal intensive care unit (NICU) serves as a crucial environment for the care and treatment of newborns who require specialized medical attention due to various health challenges. The duration of stay in the NICU is a critical parameter that reflects the complexity of the neonate's health condition and the effectiveness of medical interventions. Understanding the factors influencing NICU stay duration is essential for improving neonatal healthcare practices and optimizing resource allocation in healthcare facilities. Neonatal intensive care unit admission is a global public health issue, disproportionately affecting low- and middle-income nations. Therefore, we aimed to develop an observational study to determine the influence of Prenatal, Perinatal and neonatal factors on neonatal intensive care unit admission and stay duration in infants born in Gujarat, India. On the other hand, long hospital stay period imposes emotional and economic burdens on the family and society. Therefore, it is necessary to clarify the most important factors affecting their hospitalization duration to lessen unwanted outcomes of infants and to eliminate or relieve the problems. The prenatal period, spanning from conception to birth, sets the stage for the neonate's health trajectory, while the perinatal phase encompasses the time surrounding childbirth. Neonatal risk factors, which emerge during the first 28 days of life, further contribute to the intricacies of the neonatal health landscape. The number of newborns requiring intensive care has increased, with NICU admissions rising from 6.4% in 2007 to 7.2% in 2018[1,2]; therefore, prolonged stay of these high-risk newborns admitted to the NICU has become a concern. Though, the improvement in survival of infants is accompanied by an increase in neonatal intensive care unit (NICU) admissions. Prolonged duration of stay in the NICU increases the incidence of neonatal complications and even mortality and places a significant economic burden on families and strain on healthcare systems. Infants discharged from the neonatal intensive care unit (NICU) are at increased risk for poor neuro developmental outcomes[3-6] Prolonged NICU stay causes adverse effects on the newborn and the family.

For newborns, prolonged NICU stay exposes them longer to the hospital environments, including the noise, bright light, hospital-acquired infections, and so on, which would lead to a higher incidence of neonatal complications. [7,8] Moreover, parents are concerned about how long their newborn needs to stay in the NICU. Accurate information about the stay in NICU may alleviate unnecessary anxiety for parents. However, it is often difficult for medical staff to make accurate predictions when parents consult with them. From the healthcare system perspective, a prolonged NICU stay duration could reduce the utilization rate of beds and exacerbate the problem of inadequate healthcare resources.[9] To reduce unnecessary long duration, stay and avoid prolonged NICU stay, we must determine the risk factors affecting the NICU stay duration of newborns. Determining the risk factors for the NICU stay duration of newborns is conducive to improve the ability of predicting NICU stay duration accurately, which is critical for planning hospital resources, counselling families, stimulating quality improvement initiatives, and effectively avoiding prolonged NICU stay of newborns[10,11]. However, there is little evidence related to this issue. Therefore, the purpose of this study was to determine the Prenatal, perinatal and neonatal risk factors for the NICU stay duration of newborns from surat, gujarat, India. The significance of this research lies in its potential to inform evidence-based interventions and strategies aimed at reducing NICU stay durations, thereby minimizing the emotional, financial, and healthcare burdens on families. Identifying and addressing risk factors associated with prolonged NICU stays can lead to improved outcomes for newborns. Early intervention and tailored care plans based on a thorough understanding of contributing factors can potentially reduce the duration of NICU stays and mitigate associated complications.

AIM AND OBJECTIVES

AIM

This study aims to identify prenatal, perinatal, and neonatal risk factors for influencing long duration in NICU stay of newborns and to provide a basis for interventions to shorten NICU stay duration and factors affecting their hospitalization duration to lessen unwanted outcomes of infants and to eliminate or relieve the problems.





Pranali Thakkar and Madhavan Iyengar

OBJECTIVE

To find out Prenatal, Perinatal and neonatal risk factors affecting NICU stay duration

METHODOLOGY

Study design: Comprehensive study

Study Population: Male and Female high risk NICU Infant, from different hospital of different zones of Surat

Sampling: Purposive

Sample size: 284

Source of data: Different Paediatric hospitals with NICU centres from different zones of Surat, visited frequently, from different zones of Surat, India

Inclusion Criteria

1. Infants who admitted In NICU within one month after birth,
2. Both Male and Female NICU Infants
3. Infants admitted in NICU due to Hyperbilirubinemia, Premature, Low Birth Weight or Ventilation/oxygen support due to any reason

Exclusion Criteria

1. Infant who had a major congenital abnormality such as eg, Hydrocephalus, Spinabifida, Arnold Chiari malformation etc.

PROCEDURE

After obtained institutional ethical approval, Identification of Risk factors from Review of Literature has been done, from that list of factors determined were designated as the independent variables. The data collection phase involved gathering information from various paediatric hospitals, particularly those equipped with Neonatal Intensive Care Units (NICUs), across different zones in Surat. NOC were taken from where data have been collected, Parents were contacted and meet personally after screening Infants based on the selection criteria, the purpose of the study was explained to parents/caregiver and written informed consent was taken from them. After selection, Infants were assessed for risk factors and NICU stay duration as per assessment form assessment form includes patient's demographic data, prenatal, perinatal, neonatal history, family history and presence of factors which are in details as follows:

Prenatal Risk Factors

Maternal and Paternal age (<18 or >35 maternal,>50 Paternal), Any infection during Pregnancy, Seizure, Diabetes, Hypertension/Pre-eclampsia, Anemia, Multiple gestation, IUGR (Intra Uterine Growth Retardation), Radiationexposure, TORCH infection, History of miscarriages, Consanguineous marriage, Smoking, Abnormal fetal growth, IVF Pregnancy, Abnormal uterine blood flows, Maternal medications, Oligohydramnios

Perinatal Risk Factors

Place of delivery, Breech Presentation of fetus on vaginal delivery, Vaccum or forcepdelivery (Instrumental Delivery),Emergency LSCS, Oligohydramnios, Cord around the neck, Premature rupture of membrane, Premature birth <37weeks,Delayed Birth cry, Low Birth weight< 2.5 kg, Birthasphyxia, Meconium aspiration, Foeto-placental infection/inflammation, Choreo amnionitis ,Twins/triplets, Small for Gestational Age, Extreme low birth weight<1.5 k g



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Lack of exclusive Breast feeding, Hyperbillirubinemia, Neonatal Seizure, Low apgarscore, Neonatalhypoglycemia, Any dysmorphic or syndromic features, Any congenital anomaly, Patent Ductus Arteriosus ,Peri ventricular leukomalacia ,Respiratory Distress Syndrome, Retinopathy of prematurity, Neonatal Sepsis/meningitis And

Dependent variable

- NICU stay duration

Total 376 parents were contacted from there 316 infants met with an inclusion criteria from that 32 parents did not agree to participate in the study, so total 284 infants data has been collected

DATA ANALYSIS

The subsequent step involved performing regression analysis of 284 infants data, by using SPSS 20.0 software Between the independent variable (Prenatal, Perinatal and neonatal risk factors) in relation to the dependent variable - duration of NICU stays.

RESULT

This Table: 1 shows Prenatal factors - maternal seizure,gestational diabetes, IVF Pregnancy, maternal medication and oligohydramnios shows significant association with NICU stay duration This Table 2 shows Perinatal risk factors Birth weight, Prematurity and birth asphyxia has significant association with NICU stay duration This table 3 shows Neonatal risk factors – Neonatal seizures, LowApgar score, Neonatalhypoglycaemia and respiratory distress syndromeshows significant association with NICU stay duration From this study it has been identified that prenatal maternal seizure, gestational diabetes, IVF Pregnancy, maternal medication and oligohydramnios, Perinatal-Birth weight, Prematurity and birth asphyxia and neonatal-Neonatal seizures, Low Apgar score, Neonatal hypoglycemia and respiratory distress syndrome shows significant association with NICU stay duration

DISCUSSION

The current study identified maternal seizure, gestational diabetes, IVF Pregnancy, -maternal medication and oligohydramnios, Birth weight, Prematurity, birth asphyxia, Neonatal seizures, Low Apgar score, Neonatal hypoglycemia and respiratory distress syndrome were the predominant Prenatal, perinatal and neonatal risk factors for increase in NICU stay duration Maternal seizures can lead to fetal hypoxia (lack of oxygen) and inadequate blood flow to the fetus. This can result in damage to the developing brain and other organs. The severity and duration of the fetal distress caused by maternal seizures can influence the need for intensive care. Neonates exposed to prolonged hypoxia may require monitoring and support in the NICU, potentially prolonging their stay. Gestational diabetes can lead to increased blood glucose levels in the mother, which may cause fetal overgrowth (macrosomia) and metabolic disturbances. Babies born to mothers with gestational diabetes may be at a higher risk of respiratory distress syndrome, hypoglycemia, and other complications.

Such infants might require close monitoring and care in the NICU, potentially leading to a longer stay. *In vitro* fertilization (IVF) pregnancies may have a higher risk of preterm birth and low birth weight Certain medications taken during pregnancy can have effects on fetal development, either positively or negatively, depending on the medication. Medications with potential fetal side effects may necessitate monitoring and supportive care in the NICU. Oligohydramnios is a condition where there is an insufficient amount of amniotic fluid around the fetus, O ligohydramnios can be associated with fetal growth restriction and an increased risk of complications such as respiratory distress syndrome. Babies born in these conditions may require NICU care for respiratory support and monitoring. In summary, the discussed maternal factors play vital roles in determining NICU stay duration. Clinicians should be attuned to these factors, implementing targeted interventions to mitigate associated risks and optimize neonatal care. Future research is essential to deepen our understanding of these relationships and refine



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clinical strategies for improved perinatal outcomes. Our results were consistent with previous findings that birth weight and gestational age are the most important risk factors affecting increase in NICU stay duration.^[10, 12-18] However, there are currently no studies to explain the causes of these phenomena. Premature infants often require respiratory support, temperature regulation, and assistance with feeding. Prolonged NICU stay is common to address these developmental challenges and prevent complications associated with preterm birth. Prevention of prolonged NICU stay due to gestational age and low-birth-weight starts with a healthy pregnancy. Clinicians and researchers play a key role in improving knowledge on preterm delivery, identifying risk factors, and developing interventions that can address this syndrome.^[19] Birth asphyxia refers to inadequate oxygen supply to the newborn during the birthing process, Neonates experiencing birth asphyxia may suffer from brain damage. Prolonged NICU care is often necessary to manage complications such as hypoxic-ischemic encephalopathy (HIE) and to provide supportive therapies.^[20] Neonates with seizures may require prolonged NICU monitoring to control seizures, administer medications, and assess for potential long-term neurological effects.

There is increasing evidence that neonatal seizures have an adverse effect on neurodevelopment and may predispose to cognitive, behavioural or epileptic complication later in life.^[21] The Apgar score is a quick assessment of a newborn's physical condition immediately after birth, based on criteria such as heart rate, respiratory effort, muscle tone, reflexes, and color. A low Apgar score may indicate the need for immediate medical attention and resuscitation. Infants with low Apgar scores often require thorough evaluation and monitoring in the NICU to address any potential complications.^[22] Hypoglycemia in neonates can result from various factors, including maternal diabetes, prematurity, or inadequate glycogen stores in the newborn's liver. Prolonged NICU stay may be necessary to ensure stable glucose levels and prevent potential neurologic complications. It was accepted that even early, asymptomatic hypoglycemia could harm long-term development.^[23,24] Severe, prolonged hypoglycemia in the neonatal period can have devastating outcomes, including long-term neurodevelopmental disabilities, cerebral palsy, and death. Infants with congenital causes of persistent hypoglycemia have significantly higher rates of morbidity and mortality: 25 to 50% have developmental disabilities.^[25] RDS occurs in premature infants due to insufficient surfactant production, leading to respiratory difficulties and lung collapse. Infants with RDS often require respiratory support, including mechanical ventilation and surfactant replacement therapy. Prolonged NICU stay is common to manage respiratory issues, prevent complications, and support overall neonatal health. Neurodevelopmental delay is another complication of RDS, especially with infants who received mechanical ventilation long-term.^[26] The incidence of cerebral palsy also was increased in infants with RDS. In summary, the mechanisms underlying low birth weight, premature birth, birth asphyxia, neonatal seizures, low Apgar score, hypoglycemia, and respiratory distress syndrome contribute to the need for extended care in the NICU. Management strategies aim to address specific challenges associated with each condition, optimize organ system function, and promote overall neonatal well-being.

CONCLUSION

In conclusion, we identified several of the most critical risk factors affecting increase NICU stay duration including maternal seizure, gestational diabetes, IVF Pregnancy, -maternal medication and oligohydramnios, Birth weight, Prematurity, birth asphyxia, Neonatal seizures, Low Apgar score, Neonatal hypoglycemia and respiratory distress syndrome. Even though the majority of neonatal fatalities are preventable with effective treatments such as access to emergency obstetric and neonatal care, certain severe risk factors predispose newborns to severe complications and death, despite access to critical healthcare services. As only a few high-quality studies are available at present, well-designed and more extensive prospective studies investigating the risk factors affecting LOS-NICU are still needed in the future.



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1. Harrison WN, Wasserman JR, Goodman DC. Regional variation in neonatal intensive care admissions and the relationship to bed supply. *J Pediatr.* (2018) 192:73. doi: 10.1016/j.jpeds.2017.08.028
2. Harrison W, Goodman D. Epidemiologic trends in neonatal intensive care, 2007– 2012. *JAMA Pediatr.* (2015) 169(9):855–62. doi: 10.1001/jamapediatrics.2015.1305
3. Allen MC. Neurodevelopmental outcomes of preterm infants. *Curr. Opin. Neurol.* 2008 Apr.21(2):123–128.
4. Moore T, Hennessy EM, Myles J, Johnson SJ, Draper ES, Costeloe KL, et al. Neurological and developmental outcome in extremely preterm children born in England in 1995 and 2006: the EPICure studies. *BMJ.* 2012;345:e7961.
5. Saigal S, Doyle LW. An overview of mortality and sequelae of preterm birth from infancy to adulthood. *The Lancet.* 2008 Jan.371(9608):261–269.
6. Hintz SR, Poole WK, Wright LL, Fanaroff AA, Kendrick DE, Laptook AR, et al. Changes in mortality and morbidities among infants born at less than 25 weeks during the post-surfactant era. *Arch Dis Child Fetal Neonatal Ed.* 2005 Mar.90(2):F128–33.
7. Hintz SR, Bann CM, Ambalavanan N, Cotten M, Das A, Higgins RD, et al. Predicting time to hospital discharge for extremely preterm infants. *Pediatrics.* (2010) 125(1):E146–54. doi: 10.1542/peds.2009-0810
8. Kirkby S, Greenspan JS, Kornhauser M, Schneiderman R. Clinical outcomes and cost of the moderately preterm infant. *Adv Neonatal Care.* (2007) 7(2):80–7. doi: 10.1097/01.ANC.0000267913.58726.f3
9. Li Q, Li X, Zhang Q, Zhang Y, Liu L, Cheng X, et al. A cross-sectional nationwide study on accessibility and availability of neonatal care resources in hospitals of China: current situation. Mortality and regional differences. *Lancet Reg Health West Pac.* (2021) 14:100212. doi: 10.1016/j.lanwpc.2021.100212 18.
10. Bender GJ, Koestler D, Ombao H, McCourt M, Alskinis B, Rubin LP, et al. Neonatal intensive care unit: predictive models for length of stay. *J Perinatol.* (2013) 33(2):147–53. doi: 10.1038/jp.2012.62 19.
11. Profit J, McCormick MC, Escobar GJ, Richardson DK, Zheng Z, Coleman-Phox K, et al. Neonatal intensive care unit census influences discharge of moderately preterm infants. *Pediatrics.* (2007) 119(2):314–9. doi: 10.1542/peds.2005-2909
12. Murki S, Vardhelli V, Deshabhotla S, Sharma D, Pawale D, Kulkarni D, et al. Predictors of length of hospital stay among preterm infants admitted to neonatal intensive care unit: data from a multicentre collaborative network from India (INNC: Indian National Neonatal Collaborative). *J Paediatr Child Health.* (2020) 56(10):1584–9. doi: 10.1111/jpc.15031 25.
13. Rózańska A, Wojkowska-Mach J, Adamski P, Borszewska-Kornacka M, Gulczynska E, Nowiczewski M, et al. Infections and risk-adjusted length of stay and hospital mortality in Polish Neonatology Intensive Care Units. *Int J Infect Dis.* (2015) 35:87–92. doi: 10.1016/j.ijid.2015.04.017 26.
14. Sahiledengle B, Tekalegn Y, Zenbaba D, Woldeyohannes D, Teferu Z. Which factors predict hospital length-of-stay for children admitted to the neonatal intensive care unit and pediatric ward? A hospital-based prospective study. *Global pediatric health.* 2020 Nov; 7:2333794X209687
15. Eken MK, Tuten A, Oz kaya, E. Dincer E, Senol T, Karatekin G, et al. Evaluation of the maternal and fetal risk factors associated with neonatal care unit hospitalization time. *J Matern Fetal Neonatal Med.* (2016) 29(21):3553–7. doi: 10.3109/14767058.2016.1138466
16. Xie F, Shu Q, Chen Z-Y, Li J. Length of stay and influencing factors of NICU in the Western Hunan, an underdeveloped area of China: a 9-year retrospective study. *J Int Med Res.* (2022) 50(6):3000605221100753. doi: 10.1177/03000605221100753
17. Shah S, Zemichael O, Meng HD. Factors associated with mortality and length of stay in hospitalised neonates in Eritrea, Africa: a cross-sectional study. *BMJ Open.* (2012) 2(5):1–10. doi: 10.1136/bmjopen-2011-000792 41.
18. Ye G, Jiang Z, Lu S, Le Y. Premature infants born after preterm premature rupture of membranes with 24–34 weeks of gestation: a study of factors influencing length of neonatal intensive care unit stay. *J Matern Fetal Neonatal Med.* (2011) 24 (7):960–5. doi: 10.3109/14767058.2011.572204





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19. Di Renzo GC, Tosto V, Giardina I. The biological basis and prevention of preterm birth. *Best Pract Res Clin ObstetGynaecol.* (2018) 52:13–22. doi: 10.1016/j.bpobgyn.2018.01.022
20. Gebregziabher GT, Hadgu FB, Abebe HT. Prevalence and associated factors of perinatal asphyxia in neonates admitted to ayder comprehensive specialized hospital, Northern Ethiopia: a cross-sectional study. *International journal of pediatrics.* 2020 Oct;2020.
21. Levene, M. 2002. The clinical conundrum of neonatal seizures. *Archives of Disease in Childhood - Fetal and Neonatal Edition* 86(2):75–77
22. Pepler FT, Uys DW, Nel DG. Predicting mortality and length-of-stay for neonatal admissions to private hospital neonatal intensive care units: a Southern African retrospective study. *African Health Sciences.* 2012;12(2):166-73.
23. Tin W. Defining neonatal hypoglycaemia: a continuing debate. *Semin Fetal Neonatal Med.* 2014 Feb;19(1):27-32.2
24. Tin W, Brunskill G, Kelly T, Fritz S. 15-year follow-up of recurrent "hypoglycemia" in preterm infants. *Pediatrics.* 2012 Dec;130(6):e1497-503.
25. Thornton PS, Stanley CA, De Leon DD, Harris D, Haymond MW, Hussain K, Levitsky LL, Murad MH, Rozance PJ, Simmons RA, Sperling MA, Weinstein DA, White NH, Wolfsdorf JL, Pediatric Endocrine Society. Recommendations from the Pediatric Endocrine Society for Evaluation and Management of Persistent Hypoglycemia in Neonates, Infants, and Children. *J Pediatr.* 2015 Aug;167(2):238-45.
26. Sun H, Zhou Y, Xiong H, Kang W, Xu B, Liu D, Zhang X, Li H, Zhou C, Zhang Y, Zhou M, Meng Q. Prognosis of very preterm infants with severe respiratory distress syndrome receiving mechanical ventilation. *Lung.* 2015 Apr;193(2):249-54.

Table :1 Prenatal risk factor and NICU stay duration

Constant: 1.636, Adjusted r square value :0.255

Factor	B	t value	P value
Sex	-.069	-.448	.655
Mother age	.053	1.533	.126
father age	-.049	-1.542	.124
any infection during pregnancy	-.319	-.773	.440
Maternal Seizure	50.848	3.219	.001
Diabetes	1.635	3.153	.002
hypertension/Preeclamsia	-.085	-.335	.738
Anemia	.505	1.223	.222
MultipleGestation	-.234	-.867	.387
Intra Uterine Growth Retardation (IUGR)	.799	1.071	.285
Radiation exposure	-1.373	-.962	.337
TORCH Infection	.091	.094	.925
History of miscarriages	.300	.980	.328
Consanguineousmarriage	-.400	-.776	.438
IVF Pregnancy	.709	2.388	.018
abnormal uterine blod flow	.211	.297	.767
Maternal medication	6.576	8.656	.000
Oligohydramnios	-.593	-2.184	.030

Dependent variable: NICU stay duration





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Table: 2 Perinatal risk factors and NICU stay duration

Constant 0.509, Adjusted r square:0.015

Perinatal risk factors	B	t value	p value
Place of delivery	.208	.492	.623
Type of delivery	.291	.919	.359
If Lscs	-.038	-.201	.841
If Instrumental	.180	.503	.615
Presentation of fetus (Breech, transverse, vertex)	-.258	-1.302	.194
Birth Weight	6.082	4.388	.000
Number of babies delivered	-.152	-.675	.500
Cord around the neck	.031	.058	.954
Premature rupture of membrane	.034	.110	.912
Premature	5.194	4.388	.016
Delayed birth cry	-.336	-1.520	.130
Birth asphyxia	.502	2.169	.031
Meconium aspiration	.307	.744	.458
Fetoplacental infection	-.382	-.374	.709
Small for Gestational Age	.092	.238	.812

Dependent variable: NICU stay duration

Table : 3 Neonatal risk factors and NICU stay duration

Constant 1.352, Adjusted r square: 0.223

Neonatal risk factors:	B	t value	p value
Lack of BF	.029	.245	.806
Hyperbilirubinemia	.185	.954	.341
Neonatal seizures	.589	2.657	.008
Low apgar	2.816	5.723	.000
Neonatal hypoglycemia	2.667	4.840	.000
Any dysmorphic feature	.148	.163	.870
Patent ductus arteriosus	1.148	1.270	.205
Periventricular leukomalacia (PVL)	-.537	-.419	.676
Respiratory Distress Syndrome (RDS)	.381	1.934	.054
Neonatal Sepsis	.708	.947	.344

Dependant variable: NICU stay duration





An Examination of the Microplastic Concentration Present in Various Fish Organs of *Decapterus russelli* (Ruppell, 1830) Procured from the Kasimedu Fishing Harbour Situated along the South-Eastern Coast of India

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ABSTRACT

Human avarice and necessity have contributed to the widespread disposal of plastics in the oceans. Upon entering the ocean, these plastics are subjected to a natural weathering process that results in the formation of microscopic particulates known as microplastics. Their minuscule dimensions, measuring less than 5 mm in diameter, enable them to readily infiltrate the bodies of marine organisms. This research centers on the accumulation of microplastics in diverse anatomical regions of fish, intending to highlight the multifaceted exposure of fish to microplastics beyond mere ingestion. Almost a hundred *Decapterus russelli*, which is a member of the Carangidae family, were obtained from the Kasimedu Fish Landing Center. The digestive tract, gills, and muscle tissue of the fish were all subjected to chemical digestion. The three components under investigation exhibited the presence of microplastics, as determined by stereomicroscopy after undergoing two distinct types of filtration. Polymer analysis was performed utilizing FTIR-ATR. A cumulative count of 980 microplastics, or 16.3 pa/fish, was obtained. The magnitude of microplastics in the gut was five times that of the muscle. Microscopy revealed the presence of two distinct morphologies and four distinct colors. The frequencies of fibers were 75.52% higher than those of fragments, which accounted for 24.48%. Polypropylene and Nylon were identified

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in the isolated particulates by the peaks of the FTIR-ATR. This study demonstrates that microplastics are capable of being translocated from the gastrointestinal tract to the muscles. Due to the contamination of seafood with microplastics, this presents a significant risk to the general public who consume seafood.

Keywords: Plastic pollution, Carangidae, fibres, muscles, food safety.

INTRODUCTION

After World War II, plastics, which are long-chain molecules of polymers, acquired widespread recognition and application [1]. The global output of plastics experienced a substantial surge from 2 million metric tonnes in 1950 to 380 million metric tonnes in 2020 [2]. Urbanization and widespread utilization are the causes of this exponential growth. The ubiquitous use of plastics in daily life throughout the world is due to their non-corrosive characteristics, recyclability, affordability, and extreme durability [3]. Plasticizers, flame retardants, UV stabilizers, antifouling, and coloring agents are among the numerous additives that are incorporated during the production of plastics. In addition to enhancing the thermal and electrical conductance of the plastics, this improves their versatility [4]. The primary application of plastics in the United States is for packaging purposes, representing 35% of the nation's total plastic production. These plastics are single-use in nature. Around 13% of the plastics generated are disposed of as municipal waste. Furthermore, even in developed nations, recycling only 30% of plastics is feasible due to various impediments [5]. The remaining plastics are deposited in landfills situated along marine and terrestrial ecosystems. Plastic debris-laden effluent water from urban areas, industrial sectors, and agricultural regions, in conjunction with untreated domestic wastewater, is discharged into the ocean in large quantities, resulting in the accumulation of substantial quantities of plastic litter [6]. This contributes to the significant buildup of marine plastic pollution. Approximately 85% of the marine debris that is deposited extensively along the coastline is composed of plastics [7]. Carpenter *et al.* made the initial documentation of plastics presence in the western Sargasso Sea of England during the early 1970s. They discovered minuscule pellets of plastics with a diameter of 2.5mm to 5mm [8]. Therefore, plastic particulates with a diameter of less than 5 mm are referred to as microplastics (MPs) [9]. The aquatic environment is replete with microscopic plastic particulates that vary in size, shape, texture, and chemical composition [10-12].

Aquatic organisms are more susceptible to MPs as a result of their increased prevalence and accessibility in the marine environment. From zooplankton to apex predators, the existence of MPs has been well documented. Scientific investigations have successfully identified the entanglement of MPs in the gastrointestinal tracts of invertebrates, mammals, birds, crustaceans, and turtles [13-19]. There have been reports of MP contamination in over a hundred different species of fish, confirming both the direct and indirect ingestion of MPs through mistaken prey and the food chain [20]. In addition to obstructing the intestine and causing gastrointestinal tract abrasions, MPs in fish diminish their nutritional capacity by inducing illusory satiety and a decrease in food consumption [21]. Fish is widely utilized as a biological indicator in the assessment of water pollution. The potential health consequences of MPs can also be anticipated through the utilization of fish as biomonitors [22]. Nevertheless, this is contingent upon environmental variables, the degree of MP exposure to fish, and the physiological and metabolic processes of the species [23]. However, there is very limited work done in the analysis of MP isolation and identification from both the edible and inedible parts of the fish. The Bay of Bengal has a rich resource of marine organisms with high commercial value. Extensive fish-capturing activities are carried out by an array of fishermen along the southeast coast of the Bay of Bengal. The livelihood of many fishermen mainly depends on capturing and making a profit by selling fish. The Bay of Bengal is significantly contaminated as a consequence of the development of tourist sites along its coastline, the disposal of municipal refuse, and the release of effluent and due to well-developed fishing activities. As a consequence, substantial quantities of plastics are discharged into the Bay of Bengal. Marine organisms, such as fish, inadvertently ingest them, leading to their accumulation in both the edible and inedible portions of the fish. Estimating the level of MP contamination in fish that is of high economic importance is crucial for ensuring the safety and quality of seafood. Therefore the main objectives of the study are:





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- To investigate the presence of microplastics in the edible and inedible tissues of the pelagic fishes sold in the fish landing center.
- To estimate the number of microplastics present in the three different parts of the fish body such as the Gills, Gastrointestinal tract, and dorsal muscle tissue, and to compare their abundance.
- To Characterize the polymers present in the microplastics.

MATERIALS AND METHODS

Sampling site and collection of fish

Kasimedu is the largest fish landing center in Tamil Nadu, with coordinates 13.1251° N, 80.2955° E. To capture an assortment of palatable marine organisms, a significant number of fishing vessels depart from this area. An integrated refrigeration system is installed on these vessels to ensure the fish's preservation until they reach the shore. This region is renowned for its wide assortment of fishes, crustaceans, and molluscs that are captured and sold. Over 40% of the captured organisms are exported internationally pertaining to the seafood's nutritional significance. In the early hours of the morning, common people, market vendors, and local fishermen assemble at this location to purchase freshly caught fish directly from the vessels. To optimize the harvest fisheries' earnings, fish obtained through auctions are additionally deep frozen and transported throughout India. In December 2023, a cumulative quantity of one hundred fish samples of a single pelagic fish species belonging to the Carangidae family were acquired from the vendors at this location. Before transportation to the laboratory, they are encased in aluminium foil and deposited in an icebox. The morphometric characteristics of the species were examined before commencing any procedure. Using FAO identification keys, it was identified that the collected specimen was *Decapterus russelli* (Indian scad) [24].

Sample preparation

To prevent cross-contamination throughout the investigations, all samples are meticulously rinsed with distilled water upon entering the laboratory, eliminating any adhered contaminants. In an effort to avert experimental errors, they are thoroughly inspected for deformities, infections, and injuries. All the fish are then stored in a deep freezer at -20°C. Prior to experimentation, the fish are thawed and placed in a metallic tray. The precise measurements of the fish including their overall length and weight were documented. To retrieve the internal organs of the fish, the body is dissected by using scissors, forceps, and scalpel. The entire gastrointestinal tract from mouth to anus [25], full gill rakers [26], and dorsal muscle were isolated from the fish body and weighed accurately using a digital scale. A total of ten specimens from each anatomical part are consolidated and placed in a glass Petri dish covered with a lid.

Digestion of sample and microplastic isolation

The edible and inedible portions are transferred to a 250 ml conical flask and then the chemical procedure is carried out for digesting the organic material to obtain the MPs. A solution was formulated comprising 10% alcoholic KOH by combining ethanol and KOH granules purchased from Merck. For every sample in the aggregated set, a stock solution of 1500 ml is prepared. The Inedible parts like the gastrointestinal tract and the gills are chopped into small pieces and homogenized by using a motor and pestle. Then the edible part like the dorsal muscle is minced by using an Electric meat grinder (WelTherm, MGG-65). These three different processed samples were taken separately in a conical flask and nearly 130 ml of 10% of alcoholic KOH was added to each of the flasks and covered with aluminium foil. The Gut and gills [27] are kept in an oven at 40°C for 72 h while the muscle is maintained at 70 °C for 48 h [28]. To promote digestion and ensure uniform dispersion of the solution, the samples are manually agitated every 12-24 hours with a 1:6 ratio of organic matter to KOH [29]. The polymer present in the sample remains undamaged and unaltered throughout this chemical process for digesting organic matter [30]. Dual sets of filtration was applied to the digested sample. First, to isolate the particulates from the digested solution, a stainless sieve filter with a pore size of 0.5mm was employed. Then the resultant solution obtained is filtered using a vacuum filtration apparatus fitted with MF-Millipore™ Membrane Filter, 0.45 µm pore size, gridded (Whatman, USA). Using sterile forceps the filter paper





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containing MPs are delicately extracted from the apparatus, transferred to a pre-cleaned Petri dish and allowed to air dry for an entire night in the laboratory [31] (Figure 1).

Identification and characterization of microplastics

Using a Stereoscopic light microscope (ZEISS Stereo Discovery.V20), the filter papers are visually inspected to determine the presence of MPs. This facilitates exceptional depth perception by enabling ergonomic operation via the SYCOP touch interface. The process of identifying MPs involved the analysis of their physiochemical properties. The shape of particles enables their classification, as the thin flexible pieces are films, hard particulates are fragments, thread-like structures are fibres, and irregularly rounded structures are granules or pellets [32]. Colors and proportions also contribute to the categorization of MPs. Inbuilt software like ImageJ is used to measure the size of the observed MPs in the microscopic field of view. The characterization of the MPs was performed by using FTIR-ATR (Fourier Transform Infrared Spectroscopy with Attenuated Total Reflectance). This technique enables the quantification and identification of the organic functional groups that form the basics of the polymer composition of the MPs.

Contamination control

Prior to sample collection, airborne microorganisms that could contaminate the sample were eliminated from the laboratory through fumigation. 70% ethanol is used to clean every surface to eliminate contamination. The equipment like forceps, scissors, and Scalpel along with the apparatus like Petri dishes, and conical flasks was autoclaved before the dissection of fish. All the containers were also washed and rinsed with distilled water each time during usage in the process of experimentation. All the liquids used were filtered by using 0.1mm Whatman filter paper to remove all the unwanted particles. Procedural blanks were generated by aforementioned protocol, excluding the sample. To examine the possibility of airborne contamination in the laboratory, three sterile replicates of each sample type were implemented.

RESULTS

Characterization of *Decapterus russelli*

A wide diversity of arthropods and fish are consumed in abundance by the Indian scad, which is an exceptionally carnivorous species. The species, age, and maturation stage influence the composition of its diet. Adults consume teleost fishes, silver bellies, *Lactarius lactarius*, *Nemipterus spp.*, *Trichiurus lepturus*, *Stolephorus spp.*, and *cynoglossus spp.*, whereas juveniles consume small shrimp species such as *Acetes indicus* and Zooplanktons. Additionally, they consume a substantial amount of eels, sardines, cuttlefish, and squids in their diet. The size of the fish is directly proportional to the diameter of the food it encounters. In proportion to the extent of its gastrointestinal tract, fish can consume edible items measuring 100-110 mm in diameter [33]. The feeding behavior of *Decapterus russelli's* is remarkably unaffected by seasonal variations; in fact, the predatory activity of the fish significantly amplifies in tandem with its feeding intensity as it grows larger. Indian scad has two potential routes of MP accumulation as it is a piscivorous and invertivorous organism. Firstly, they can ingest MPs directly, as the MPs themselves are less than 5mm in size. Secondly, they can accumulate MPs through the organism it consumes, which have already ingested the MPs. Out of the total of one hundred fish collected, fifty percent were identified as females and the other fifty as males. Overall, the fish weighed 155.1 ± 5.7 g and measured 15.32 ± 0.66 cm in length.

Accumulation and Comparison of MPs Isolated

Chemical digestion and microscopic examination revealed that MPs had accumulated in sixty percent of the collected samples. A total count of 980 MPs was obtained from 60 fish, with an average particle abundance of 16.33 per fish. It has ingested nearly 550 MPs which were found in the gut, 320 MPs were found in the gills accumulated via the water circulation, and due to the translocation from the gut to muscle, 110 MPs were found in the dorsal part of muscle. After a detailed examination of the Inedible parts like the gut and gills as well as the edible part like a muscle, revealed two different morphometrics like fibres (75.52%) (Figure.2 a, b) and fragments (24.48%) (Figure.2 c, d) with





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four distinct colors such as blue, green, yellow, and white. The fibres dominated in proportion when compared to the fragments obtained. The order of occurrence of the MPs is Blue fibres (48.97%) > Green fibres (26.53%) > Yellow fragment (13.26%) > White fragment (11.22%) (Figure 3). All three organs showed the presence of both distinct types of MPs, but the proportion of the MPs in each part varied significantly (Table 1) (Figure 4). The Gut had the higher number as well as percentage of MPs (56.12%) with 9.16 MPs/per gut which is followed by gills (32.65%) with 5.33 MPs/gill and the muscle had the lowest occurrence of 11.22% with 1.83 MPs/tissue (Figure 5). Thus, the above results indicate that the gut has five times greater MPs than the muscle and the gills have thrice the MPs when compared to the edible part of the fish.

Polymer estimation from the isolated MPs

Images of MPs were captured using software installed in the stereomicroscope and subsequently, the polymer composition of the isolated MPs was identified using Fourier transform infrared spectroscopy with attenuated total reflectance (FTIR-ATR Model: SHIMADZU-QATR 10). A unique functional group and a member of a homologous series compose each plastic particulate. They are both intermolecularly bonded together to create a monomer. The basal structure of the MPs is composed of a polymer formed when all of these monomers are interconnected via strong bonds. In the form of infrared peaks, FTIR-ATR provides the signature spectrum of these chemical compounds. Upon examination, it was discovered that the Nylon polymers comprised the greatest number of MPs, such as fibres, while the polymer in fragments consisted of polypropylene. C-H stretching, N-H stretching, C-N stretching, CH₂ stretching, and C=O stretching were represented by the well-formed peaks observed for both the blue and green fibres between wavenumber 3000cm⁻¹ and 1000 cm⁻¹. These peaks validate the existence of Nylon polymer in the sample (Figure 6). The characteristic spectral features of polypropylene were observed in both the yellow and black fragments, which exhibited FTIR-ATR peaks between 3000 cm⁻¹ and 1500 cm⁻¹. These peaks corresponded to C-H stretching and CH₂ bending present in the structure of the polymer polypropylene (Figure 7).

DISCUSSIONS

A substantial quantity of MPs was detected in the *Decapterus russelli*, a widely consumed scad, that was obtained from the Bay of Bengal. This finding provides a definitive indication of the extent of MP contamination along the Chennai coastal area. Gills and the gut are the primary focus of research conducted in other regions [34]; the edible part like muscle is very less studied [35,36]. Thus, by the above-performed experiment, both fishermen and the general public are made cognizant of the inexorably prevalent issue of seafood contamination through the practical data acquired from the experiment's outcomes regarding the presence of MPs in muscle. However, there are still numerous unexplored facets about the presence of MPs in fish organs other than the intestine. Despite reports indicating that the MPs may be translocated to the muscle [37,38], the precise mechanism underlying their ability to traverse the blood to enter the sarcomere remains unknown. Extremely limited experiments were conducted on the translocation of MPs [39-42]. Therefore, future research must concentrate on conducting targeted experiments to elucidate the molecular and cellular mechanisms underlying the translocation of MPs to obtain a comprehensive understanding of their behaviour within living organisms. Upon comparing the findings of the aforementioned experiment with other research studies, it was observed that the gut of Indian scad had a greater concentration of MPs around 9.16 pa/fish, in contrast to the 0.6 pa/fish reported by Baalkhuyur et al (2020) in the Persian Gulf [17]. Daniel et al (2020) demonstrated a significantly low prevalence of MPs in both the edible (41%) and inedible (7%) portions [43]. In contrast, our findings revealed a twofold increase in the presence of MPs in both the edible and inedible portions. This investigation solely collected fibres and fragments, with fibres being in higher proportions in three body parts of the fish. These findings align with the results of previous studies, which confirm the fibres are the most abundant MPs in the ocean due to various sources of their emergence [44,45]. The preponderance of fibres in the gut, gills, and muscles throws light on the extensive fishing activities, cargo exchange, and other ocean-related commerce that releases heavy loads of waste into the ocean [46]. The quantity of fragments serves as an indication of both natural weathering processes and the discharge of residential sewage into the Bay of Bengal. The variation in colors of MPs mostly stems from many sources from which they originate [47-49].





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CONCLUSIONS

This research offers initial evidence of MPs presence in diverse organs of commercially valuable carangid species like *Decapterus russelli*. The predatory behavior of the *Decapterus russelli* is responsible for the erroneous build-up of MPs in its body. Over fifty percent of the collected samples confirmed the presence of MPs in three distinct body regions, including the gills, gut, and muscle. In the following order, the prevalence of MPs varied between body parts of fish: gut (56.12%) > gills (32.65%) > muscle (11.22%). This clearly indicates that the gut contains five times more MPs than muscles, implying that only 25% of the ingested MPs are translocated to muscles, while the other 75% are expelled by feces. The findings of this research demonstrate that MPs may enter fish bodies via gills as well as by ingestion and water circulation. The primary concern raised by the research findings is the potential presence of MPs in edible components, such as muscle, which are widely ingested by the local populace. Thus, there is a high likelihood that individuals will accumulate MPs in their stomachs after consuming seafood contaminated with MPs; these particles are capable of translocating to human vital organs and affecting their metabolism. Additionally, the numerous colorants applied to MPs may cause severe toxicity in humans. Therefore, fish function as a route for the transmission of MPs from the ocean to the human body.

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REFERENCES

1. Law KL. Plastics in the marine environment. Annual review of marine science. 2017;9:205-29.
2. Europe P. Plastics Europe Association of plastics manufacturers plastics – the facts 2021 an analysis of European plastics production, demand and waste data. Plastics-the Facts. 2021;2021:34.
3. Auta HS, Emenike CU, Fauziah SH. Distribution and importance of microplastics in the marine environment: a review of the sources, fate, effects, and potential solutions. Environment international. 2017;102:165-76.
4. Akdogan Z, Guven B. Microplastics in the environment: A critical review of current understanding and identification of future research needs. Environmental pollution. 2019;254:113011.
5. Pruter AT. Sources, quantities and distribution of persistent plastics in the marine environment. Marine Pollution Bulletin. 1987;18(6):305-10.
6. Zhang H. Transport of microplastics in coastal seas. Estuarine, Coastal and Shelf Science. 2017;199:74-86.
7. Geyer R. A brief history of plastics. Mare plasticum-the plastic Sea: Combatting plastic pollution through science and art. 2020:31-47.
8. Carpenter EJ, Smith Jr KL. Plastics on the Sargasso Sea surface. Science. 1972;175(4027):1240-1.
9. Andrady AL, editor. Plastics and the Environment. John Wiley & Sons; 2003.
10. Duis K, Coors A. Microplastics in the aquatic and terrestrial environment: sources (with a specific focus on personal care products), fate and effects. Environmental Sciences Europe. 2016;28(1):2.
11. Andrady AL. Microplastics in the marine environment. Marine pollution bulletin. 2011;62(8):1596-605.
12. Wagner M, Scherer C, Alvarez-Muñoz D, Brennholt N, Bourrain X, Buchinger S, Fries E, Grosbois C, Klasmeier J, Marti T, Rodriguez-Mozaz S. Microplastics in freshwater ecosystems: what we know and what we need to know. Environmental Sciences Europe. 2014;26(1):1-9.
13. Desforges JP, Galbraith M, Dangerfield N, Ross PS. Widespread distribution of microplastics in subsurface seawater in the NE Pacific Ocean. Marine pollution bulletin. 2014;79(1-2):94-9.
14. Alomar C, Estarellas F, Deudero S. Microplastics in the Mediterranean Sea: deposition in coastal shallow sediments, spatial variation and preferential grain size. Marine environmental research. 2016;115:1-0.



**Yasmeen Ali Rafi et al.,**

15. Karbalaei S, Golieskardi A, Hamzah HB, Abdulwahid S, Hanachi P, Walker TR, Karami A. Abundance and characteristics of microplastics in commercial marine fish from Malaysia. *Marine pollution bulletin*. 2019;148:5-15.
16. Al-Salem SM, Uddin S, Lyons B. Evidence of microplastics (MP) in gut content of major consumed marine fish species in the State of Kuwait (of the Arabian/Persian Gulf). *Marine Pollution Bulletin*. 2020;154:111052.
17. Baalkhuyur FM, Qurban MA, Panickan P, Duarte CM. Microplastics in fishes of commercial and ecological importance from the Western Arabian Gulf. *Marine Pollution Bulletin*. 2020;152:110920.
18. James K, Vasant K, Padua S, Gopinath V, Abilash KS, Jeyabaskaran R, Babu A, John S. An assessment of microplastics in the ecosystem and selected commercially important fishes off Kochi, south eastern Arabian Sea, India. *Marine Pollution Bulletin*. 2020;154:111027.
19. Kor K, Mehdiinia A. Neustonicmicroplastic pollution in the Persian Gulf. *Marine pollution bulletin*. 2020;150:110665.
20. Arias AH, Ronda AC, Oliva AL, Marcovecchio JE. Evidence of microplastic ingestion by fish from the Bahía Blanca estuary in Argentina, South America. *Bulletin of environmental contamination and toxicology*. 2019;102(6):750-6.
21. Moore CJ. Synthetic polymers in the marine environment: a rapidly increasing, long-term threat. *Environmental research*. 2008;108(2):131-9.
22. Petersen F, Hubbart JA. The occurrence and transport of microplastics: The state of the science. *Science of the Total Environment*. 2021;758:143936.
23. Bray L, Digka N, Tsangaris C, Camedda A, Gambaiani D, de Lucia GA, Matiddi M, Miaud C, Palazzo L, Pérez-del-Olmo A, Raga JA. Determining suitable fish to monitor plastic ingestion trends in the Mediterranean Sea. *Environmental pollution*. 2019 Apr 1;247:1071-7.
24. Abdussamad EM, Rohit P, Mohamed OM. A field identification key for 20 genera of Family Carangidae. *Journal of the Marine Biological Association of India*. 2007;49(2):141-7.
25. Lusher AL, O'Donnell C, Officer R, O'Connor I. Microplastic interactions with North Atlantic mesopelagic fish. *ICES Journal of marine science*. 2016;73(4):1214-25.
26. Su L, Deng H, Li B, Chen Q, Pettigrove V, Wu C, Shi H. The occurrence of microplastic in specific organs in commercially caught fishes from coast and estuary area of east China. *Journal of hazardous materials*. 2019;365:716-24.
27. Ali Karami AK, AbolfazlGolieskardi AG, Ho Yu HY, Larat V, BabakSalamatinia BS. Microplastics in eviscerated flesh and excised organs of dried fish.
28. Dehaut A, Cassone AL, Frère L, Hermabessiere L, Humber C, Rinnert E, Rivière G, Lambert C, Soudant P, Huvet A, Duflos G. Microplastics in seafood: Benchmark protocol for their extraction and characterization. *Environmental pollution*. 2016;215:223-33.
29. deVries AN, Govoni D, Árnason SH, Carlsson P. Microplastic ingestion by fish: Body size, condition factor and gut fullness are not related to the amount of plastics consumed. *Marine pollution bulletin*. 2020;151:110827.
30. Barboza LG, Lopes C, Oliveira P, Bessa F, Otero V, Henriques B, Raimundo J, Caetano M, Vale C, Guilhermino L. Microplastics in wild fish from North East Atlantic Ocean and its potential for causing neurotoxic effects, lipid oxidative damage, and human health risks associated with ingestion exposure. *Science of the total environment*. 2020;717:134625.
31. Gayathry S, Sarlin PJ, Thomas JA, Augustine A, Darshitha S, Morris S. Microplastics in the edible and inedible tissues of *Mugilcephalus* from Ashtamudi Lake, a Ramsar site in Kollam, Kerala, India.
32. Jabeen K, Su L, Li J, Yang D, Tong C, Mu J, Shi H. Microplastics and mesoplastics in fish from coastal and fresh waters of China. *Environmental pollution*. 2017;221:141-9.
33. Poojary N, Tiwari LR, Jaiswar AK. Food and feeding habits of the Indian scad, *Decapterus russelli* (Ruppell, 1830) from Mumbai waters, north-west coast of India. *Indian J. Fish*. 2010;57(4):93-9.
34. Akoueson F, Sheldon LM, Danopoulos E, Morris S, Hotten J, Chapman E, Li J, Rotchell JM. A preliminary analysis of microplastics in edible versus non-edible tissues from seafood samples. *Environmental pollution*. 2020;263:114452.



**Yasmeen Ali Rafi et al.,**

35. Huang JS, Koongolla JB, Li HX, Lin L, Pan YF, Liu S, He WH, Maharana D, Xu XR. Microplastic accumulation in fish from Zhanjiang mangrove wetland, South China. *Science of the Total Environment*. 2020;708:134839.
36. Wang Q, Zhu X, Hou C, Wu Y, Teng J, Zhang C, Tan H, Shan E, Zhang W, Zhao J. Microplastic uptake in commercial fishes from the Bohai Sea, China. *Chemosphere*. 2021;263:127962.
37. Ma C, Chen Q, Li J, Li B, Liang W, Su L, Shi H. Distribution and translocation of micro- and nanoplastics in fish. *Critical Reviews in Toxicology*. 2021;51(9):740-53.
38. Di Giacinto F, Di Renzo L, Mascilongo G, Notarstefano V, Gioacchini G, Giorgini E, Bogdanović T, Petričević S, Listeš E, Brkljača M, Conti F. Detection of microplastics, polymers and additives in edible muscle of swordfish (*Xiphias gladius*) and bluefin tuna (*Thunnus thynnus*) caught in the Mediterranean Sea. *Journal of Sea Research*. 2023;192:102359.
39. Batel A, Borchert F, Reinwald H, Erdinger L, Braunbeck T. Microplastic accumulation patterns and transfer of benzo [a] pyrene to adult zebrafish (*Danio rerio*) gills and zebrafish embryos. *Environmental pollution*. 2018;235:918-30.
40. Batel A, Baumann L, Carteny CC, Cormier B, Keiter SH, Braunbeck T. Histological, enzymatic and chemical analyses of the potential effects of differently sized microplastic particles upon long-term ingestion in zebrafish (*Danio rerio*). *Marine Pollution Bulletin*. 2020;153:111022.
41. da Costa Araújo AP, da Luz TM, Rocha TL, Ahmed MA, e Silva DD, Rahman MM, Malafaia G. Toxicity evaluation of the combination of emerging pollutants with polyethylene microplastics in zebrafish: Perspective study of genotoxicity, mutagenicity, and redox unbalance. *Journal of Hazardous Materials*. 2022;432:128691.
42. Bhagat J, Zang L, Nishimura N, Shimada Y. Zebrafish: An emerging model to study microplastic and nanoplastic toxicity. *Science of The Total Environment*. 2020;728:138707.
43. Daniel DB, Ashraf PM, Thomas SN. Microplastics in the edible and inedible tissues of pelagic fishes sold for human consumption in Kerala, India. *Environmental Pollution*. 2020;266:115365.
44. Giani D, Baini M, Galli M, Casini S, Fossi MC. Microplastics occurrence in edible fish species (*Mullus barbatus* and *Merluccius merluccius*) collected in three different geographical sub-areas of the Mediterranean Sea. *Marine pollution bulletin*. 2019;140:129-37.
45. Bagheri T, Gholizadeh M, Abarghouei S, Zakeri M, Hedayati A, Rabaniha M, Aghaeimoghadam A, Hafezieh M. Microplastics distribution, abundance and composition in sediment, fishes and benthic organisms of the Gorgan Bay, Caspian sea. *Chemosphere*. 2020;257:127201.
46. Akhbarizadeh R, Moore F, Keshavarzi B. Investigating a probable relationship between microplastics and potentially toxic elements in fish muscles from northeast of Persian Gulf. *Environmental pollution*. 2018;232:154-63.
47. Abadi ZT, Abtahi B, Grossart HP, Khodabandeh S. Microplastic content of Kutum fish, *Rutilus rutilus* in the southern Caspian Sea. *Science of the Total Environment*. 2021;752:141542.
48. Abbasi S, Soltani N, Keshavarzi B, Moore F, Turner A, Hassanaghaei M. Microplastics in different tissues of fish and prawn from the Musa Estuary, Persian Gulf. *Chemosphere*. 2018;205:80-7.
49. Akhbarizadeh R, Moore F, Keshavarzi B. Polycyclic aromatic hydrocarbons and potentially toxic elements in seafood from the Persian Gulf: presence, trophic transfer, and chronic intake risk assessment. *Environmental geochemistry and health*. 2019;41:2803-20.





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Table 1. Abundance of MPs in different parts of *Decapterus russelli*. (+) Denotes the presence of MPs and (-) signifies the absence of MPs in the pooled sample of fish.

N=10	MPs	Amount of Mps in Gastrointestinal Tract				Amount of Mps in Gills				Amount of Mps in Dorsal muscle			
		Blue fibres	Green fibres	Yellow fragment	White fragment	Blue fibres	Green fibres	Yellow fragment	White fragment	Blue fibres	Green fibres	Yellow fragment	White fragment
1	+	44	22	12	10	30	15	10	8	4	2	2	3
2	-	----	----	----	----	----	----	----	----	----	----	----	----
3	+	43	20	10	8	25	10	5	3	5	3	3	2
4	-	----	----	----	----	----	----	----	----	----	----	----	----
5	+	33	18	9	5	18	8	5	8	11	7	3	2
6	+	58	15	7	5	17	20	13	9	12	5	3	3
7	-	----	----	----	----	----	----	----	----	----	----	----	----
8	+	42	27	13	15	22	12	12	10	8	5	2	3
9	-	----	----	----	----	----	----	----	----	----	----	----	----
10	+	60	48	14	12	38	15	5	2	10	8	2	2
Total	----	280	150	65	55	150	80	50	40	50	30	15	15

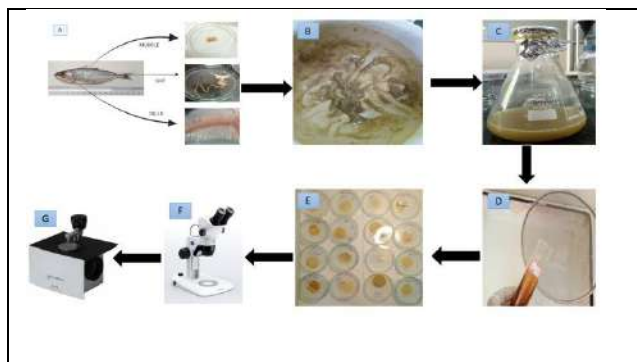


Fig.1. Represents all the steps involved in the microplastic isolation from the sample. A) Gut, Gills, and Muscles collected from the sample, B) Homogenation, C) KOH digestion, D) Sieve filtration, E) Air-dried filters collected after vacuum filtration, F) Microscopic Examination, G) FTIR-ATR analysis


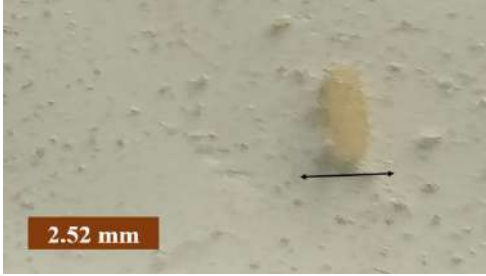
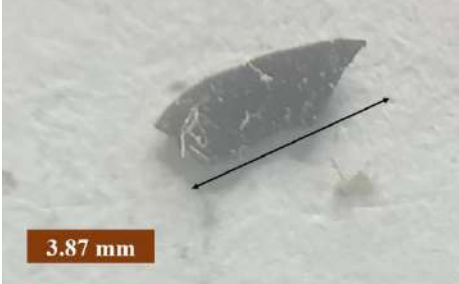


Fig.2. Microscopic images showing isolated MPs. a) Blue fibres





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<p>Fig.2. b) Green fibres</p>	<p>Fig.2. c) Yellow fragment</p>
	
<p>Fig.2. d) Black fragment.</p>	





Mastering Mathematical Skills through Classic Game Pallanguzli

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ABSTRACT

The Trick of Learning is a graphic novel that defies the upskilling of mathematics that involved remembering or following the rules to obtain solutions. It is concluded that through illustrated processes, learners can learn and develop mathematical interest through reflecting on and appreciating what exists in their traditional games. The purpose of this paper is to discuss how to learn mathematics skills by playing the traditional game "Pallanguzhi". With this paper, we bring you information about traditional knowledge and Ethnomathematics. We attempt to provide an overview of the Pallanguzhi game as well as discuss how it improves memory, attention, estimation, calculation skills, problem-solving skills, foundation skills, and reasoning.

Key words: Ethnomathematics, Combinatory and Problem solving skills.

INTRODUCTION

Mathematics has been a part of every culture throughout recorded history. The contributions of varied customs permit us to achieve a good knowledge of mathematics. By placing appropriate mathematical skills within their cultural context, teachers recognize and value diversity [1]. This offers a platform to examine the deeper issues of educational

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equality, students' empowerment, prejudice diminution, and cultural pluralism. A race's traditional knowledge is bound up with its culture, religion, language, festivals, and functions. Every race is identified by the above events. Also, it grows with the events. Every event helps develop many skills among a particular race. Indigenous mathematical knowledge has been referred to as frozen knowledge because it remains with the traditions without being fully utilized for these societies' educational, social, and even economic development [2].

The "count-and-capture" game Pallanguzhi was invented for two players in south India. For people of any stage of life, it is simple to learn and extremely entertaining. The goal of each player's Pallanguzhi game is to collect the most seeds, therefore players take turns moving seeds about the board. This game requires advanced planning. To find the best movements, players must imagine the potential outcomes of their actions and test several strategies. Pallanguzhi is one of the ancient and well recognized Mathematical games in the Universe. The ultimate objective of the activity, which is mostly based on mathematical concepts, is to transfer the beans or shells (the playing objects) among various wells as well as compartments to detain pieces against someone's opponent. By using counting strategies, players capture or avoid being captured on the game board. Children can inexpensively make the game board using empty egg cartons and use lima beans for the playing pieces. Based on the setting in which it is played, it may also go by the names Bao, Oware, or Sungka and use a variety of rules, game boards, and playing elements. For instance, the Masai of Kenya use an airplane with up to 50 compartments in each row and refer to the game as Kiuthi. [3, 4].

Ethnomathematics

Mathematics has been considered one of the most important subjects that one studies in school in order to comprehend and utilize algorithms written in numbers and symbols. (Patricia Moyer, 2001) Mathematics has unchanging principles and rules developed by the ancestors, and it is often presented as a set of statics. But this is not connected to the current problem. According to Barta, Cuch, and Exton [5, 6], few researchers have found that many pupil and especially the majority of minority students, think that mathematics was created and is held by a group that they do not belong to. A tie has been made between achievement score gaps. Ethnomathematics, which has been around for more than two decades, has shown dramatic changes and powerful insights in the field of mathematics and in cross-cultural analysis [7]. Additionally, Jorgensen, Sullivan, & Youdale [8] state that a wide range of factors should be considered to make effective teaching occur in a multi-dimensional learning ecology. A variety of factors need to be considered. The study will utilize the participatory action research method. Participatory action research recognizes community members as experts and it is empowering the communities which are enabled to find their own solutions to local issues. The study of the connections in between mathematics as well as cultures is known as ethnomathematics [9]. According to Alan Bishop, a renowned expert in ethnomathematics, people have used mathematics throughout history and throughout the world to count, measure, design, identify, demonstrate, and play [10]. Elmer Ghostkeeper, a math expert from Alberta, Canada, was questioned why he believed that many American Indian and First Nations pupil had difficulty with math. Elmer, a Métis (First Nation) person, said, "Several of our children difficulty with mathematics due to the numbers are unable to dance!" [6]. Pallanguzhi is an excellent method to get kids interested in ethnomathematics, which is the study of the connections between mathematics and culture. Although the origin of Pallanguzhi is unclear, it was introduced to North America via African slaves that was a popular game in south India. The amount of rows, pits, or seeds can be changed to generate countless game variations. Your children will have a great chance to learn about and appreciate a different culture with this game.

History of Pallanguzhi

Mankala is the most famous and oldest mathematical and strategic board game in the world. This game is played throughout the world in 800 variants. Depending upon a various culture and countries, mankala may have different rules and is played on variety of boards. Originating in Tamilnadu with the name Pallanguzhi (the southern part of India) and being mankala, the national game of Africa, Pallanguzhi is losing its importance and being lost now days. The game Pallanguzhi is played with minor changes all around the world. Famous game in Africa, Arabian countries, and western countries.





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A Kriti, the ideal form and ruler of Ayodhya! Your wonderful words, which you and Sita delivered while looking at each other and playing the game of Pallanguzhi, filled my ears with joy and my heart with genuine love and understanding. With her and triumphed, which Bharata and Hamiman heard. Note: Rama proves masculine superiority through this Kriti (Hindu music of devotion common in southern India). He triumphs in the realm of women. Pallanguzhi (Pallanguzhi or Pallanguzhi) is a popular traditional indigenous mankala game played among the Tamils, particularly in south India. Pallanguzhi, a traditional game of Tamilnadu, has a 3000 year rich history. In Tamil, pal means "many" and kuzhi (guli or guzhi) means "pit", 'Pallanguzhi' means "many pits". This game was named so because pits (kuzhi in Tamil) were dug on the ground and played in. Also, it had the name Pathinankuli, as it has fourteen pits with seven pits on either side. Over a rectangular board containing two rows and seven columns, this traditional game is played. totaling fourteen pits (cups). Later, it was renamed Pallanguzhi.

Pallanguzhi is often composed of wooden or metal. Shells of cowries (sozhi in Tamil) with tamarind seeds, the pits on the board are typically filled with tamarind seeds, cowry shells (sozhi in Tamil), or small stones. When parents play this game with their children, the relationship between them is strengthened. Girls attending puberty were given Pallanguzhi for playing. Girls of the same age avoided men's vision by playing Pallanguzhi. Playing Pallanguzhi becomes an exercise for the fingers and gives clarity in dealing with numbers. Women who take up Sivarathiri and Vaikunda Ekadasi fasting, used to play Pallanguzhi to keep themselves awake. The physical and mental skills developed due to these games were also lost with their disappearance. Women equalizing themselves to men in all fields and hardly allotting time for games are the reasons for the disappearance of the game. Pallanguzhi helps to enhance the numerical skills, and the differently abled develop optimism by playing Pallanguzhi.

Playing Method

Generally, the participants are two in number; when participants become three, it is called Rajapandi, and when only one plays, it is called Sithapandi (sit reminding me of Sithadevi playing alone in Asokavanam). Also, it holds another name, Kaipandi. Two participants face each other, with seven pits for every participant. In the beginning, every pit is filled with five tamine seeds. The beginner starts by picking the seeds from any one of the pits in his or her side. The beginner's pit is emptied as he plays. He or she can continue the game by playing the seeds from the next pit. Once the pit is emptied, he starts continuing the game by picking from the next pit. This is named "Thudaiythu yaduthal". For every seed dropped in the empty pit, Once it becomes four, that is called a pasu and can be taken by the player. Once seeds are taken in all pits by both players, a round gets completed. If a player gets fewer than 15 seeds, he or she should empty three pits on his or her side and continue the game.

Mathematics of Pallanguzhi

The game Pallanguzhi is found to be simple, but they are deterministic and have a few options for each move, typically not more than a couple of pits in a row, and it might be challenging to remember the contents of a packed pit. It is challenging to predict the effects of even a few moves in advance, much less the game's ending, since a single move might affect the contents of all pits on the board.

Pallanguzhi positions

The number of potential locations is a mathematical characteristic that may shed light on the Pallanguzhi game's complexity. A position in the game of Pallanguzhi involves a specific distribution of counters over the board's pits as well as any counters that have been captured and are either stored in the board's stores or are being maintained by the players in the absence of stores [11]. A position also contains information on the player who will move next. The quantity of pits (and storage) and counters determines the number of slots that are available. The number N may be calculated using the formula below, which is derived from fundamental combinatorics:

$$N = \frac{p(q+r-1)!}{q!(r-1)!}$$





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In this equation, p stands for the total number of players, q for all the counters, and r for all the pits and stores, or all the pits increased by the number of players in the absence of stores. With an increase in pits and counters, the number N rises quite quickly. The number of positions on a Pallanguzhi board with a pair of six pits and two stores is shown in the table below for two players. Naturally, if only the counters that are currently in play are considered (as is done, for instance, in [12], the number of viable situations diminishes. During games, a finite number of all available places can actually be used. This is dependent on the game's starting position and the specific rules. It seems that only a small number of the Pallanguzhi game's unusual locations can be fully grasped mathematically.

Mathematical skills from Pallanguzhi

Mathematical skills being the basic for all the skills is development by Mental Math's, decision making skill development, thinking ability, exercise for fingers. The Tamils knew that learning mathematics through games helped them handle difficult circumstances easily and to solve and avoid them using their mathematical skills. Games played using mathematical numbers develop memory power and problem-solving skills. Pallanguzhi gives students the chance to hear and discuss mathematical concepts. Students can start off utilizing their own unique terminologies, and their instructor or other students can help them transition to the formal symbols and language of mathematics that best express their thoughts (for instance, adding or subtracting stones by adding or removing some of them, respectively). Students can discuss both the tangible mathematical concepts occurring on the gaming board and their mathematical mental illustrations of possible movements. Students can also be required to justify their actions to an adversary.

Enhances memory, Attention and Estimation

This game builds decision-making, mathematical, and motor skills, enhances thinking ability, and increases analytical skills. This game helps to coordinate easily with others. Students have a great chance to master modular arithmetic in Pallanguzhi. Students use the remainder to calculate exactly where their stone will go in relation to the starting pit at the conclusion of the round by mentally dividing the number of objects they are disseminating by the number of pits and their Pallanguzhi. The last seed would land two pits beyond their initial position, for instance, if players had two, fifteen, or twenty-eight seeds in a pit.

Calculation skills

Playing Pallanguzhi becomes an exercise for the fingers and gives clarity in dealing with numbers. Both the hands and eyes synchronize to work, which also helps stimulate brain activity. This helps to increase one's performance and faster calculating skills.

Problem Solving Skills

Pallanguzhi is a very powerful tool for all, particularly students, to solve life-oriented problems strategically. Players will accumulate grounding knowledge and gain economic thoughts experimentally. They notice, attend, and browse many methods multidimensionally through play. Players will gain the surefootedness to face difficult situations and to generate new ideas. Performers have a choice for solving the issue: they can capitalize on the vacant pots to capture seeds, or they can transcend more by tooling to obtain another chance and subsequently another opportunity to move seeds into their side.

Foundation Skills

This game brings about skill development and enhances it among children and adults. It also improves observation and analytical skills. Pallanguzhi supports to develop visualisation skills. The total number of stones in a hole provides a good realistic illustration of adding and subtracting, counting, and subdividing. Pallanguzhi has a strong relationship with leftovers. Players can compute the leftover after dividing their stones evenly among the playing field to determine where their final seed will go. Students gain a deeper, more flexible comprehension when they can grasp these concrete concepts and turn them into mental representations. Visualizing your prospective actions is a crucial part of the game, which calls for pupils to be familiar with the number of stones that would be in each pot. Players must refine their spatial awareness and logic in order to disperse the stones in the pot of their choice.





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Reasoning

The game will provide students practice understanding an unidentified mathematical issue. As kids learn efficient playing techniques in accordance with the patterns they observe, they will gain confidence. They will have the ability to capable of rationally argue their judgments if they have a clear understanding of which techniques are most effective and why. Students frequently employ the tactic of attempting to perform as many successive turns as they can. When employing this tactic, the optimal starting move is to distribute the stones from the pit, causing the final stone to land upon the Pallanguzhi pocket and so resulting in another turn.

CONCLUSION

In recent days, men, women, and children addicted to television, computers, and mobiles isolate themselves from society. Entertainment shifting towards smartphones is the reason for the disappearance of our traditional games. This addiction to the media leads to many psychological and physiological problems. Pallanguzhi game can create numerous questions to mathematicians. Very few questions are still set forward, and only some issues can be resolved without the use of mathematical science. Rarely, these solutions can help players better their Pallanguzhi strategy. This paper is expected to inspire other readers to raise their own additional queries. Interdisciplinary research has a lot to gain from the Pallanguzhi game. The use of a computer to facilitate cognitive psychology research has been demonstrated in the ongoing Dakon study. Players' learning dynamics were investigated using a clever computer software. As a stiff opponent to play against, the program was used. It is proposed to play an algorithmic game against knowledge. Based on its principle, this algorithm can be used to determine the strategy a human opponent is employing when playing against mathematics. Therefore, this can be applied to the advancement of psychological study on Pallanguzhi learning.

REFERENCES

1. Ascher and Martha, "Mathematics Elsewhere: An Exploration of Ideas across Cultures", Princeton, NJ: Princeton University Press, 2002.
2. Gay, J & Cole, M, "The New Mathematics and an Old Culture", A Study of Learning among the Kpelle of Liberia. New York: Holt, Rinehart and Winston, 1967.
3. Patricia Moyer, "Making mathematics culturally relevant", Mathematics teaching, 2001.
4. Patricia Moyer, "Are we having fun yet? How teachers use manipulatives to teach mathematics", Educational studies in Mathematics, 2001.
5. Barta, J, Cuch, M, & Exton, V. N, "When numbers dance for mathematics students: Culturally responsive mathematics instruction for Native youth. In S. T. Gregory (Ed.)", Voices of Native American Educators (pp. 145–166). Lanham, MD: Lexington Books, 2012.
6. Barta, Jetté & Wiseman, "Dancing numbers: Cultural, cognitive, and technical instructional perspectives on the development of Native American mathematical and scientific pedagogy", Educational Technology Research and Development, vol. 51, issue. 2, pp. 87-97, 2003.
7. Eglash & Ron, "Computation, Complexity and Coding in Native American Knowledge Systems", In Changing the Faces of Mathematics: Perspectives on Indigenous People of North America, Judith Hankes and Gerald Fast Editor, NCTM Publisher, 2002.
8. Jorgensen, R, Sullivan, P & Youdale R, "Knowing Where You Are Going Helps You Know How to Get There", APMC. 2009.
9. D'Ambrosio, U, "What is Ethnomathematics and how can it help children in schools?", Teaching Children Mathematics, vol. 7, issue. 6, pp. 308-310, 2001.
10. Bishop, A. J, "Mathematics enculturation: A cultural perspective on mathematics education", Dordrecht, Netherlands: Kluwer, 1988.
11. Jeroen Donkers, Jos Uiterwijk & Alex de Voogt, "Mancala games - Topics in Mathematics and Artificial Intelligence", 2003.



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12. Retschitzki, "Strategies of expert awele players" International Colloquium "Board Games in Academia III" Florence, April 12-15 1999.

Table 1

Counter per pit	p	N
	1	28
	2	210
	3	1,120
	4	4,760
	5	17,136
1	12	10,400,600
2	24	7,124,934,600
3	36	$5,25194 \times 10^{11}$
4	48	$1,313244 \times 10^{13}$
5	60	$1,725415 \times 10^{14}$
6	72	$1,4776 \times 10^{15}$





RESEARCH ARTICLE

Identification of Potential Phytochemicals from the Indian Medicinal Plants for Treating Pneumoconiosis– An *In silico* Approach

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ABSTRACT

Pneumoconiosis is a group of heterogeneous occupational interstitial lung diseases caused by the inhalation of mineral dust in the lungs, which leads to lung dysfunction. This dust is primarily inorganic particles, such as free silica dust, asbestos fibers, dust from coal mines, and mixed silicate dust. The present study was designed to find the potential phytochemicals from Indian medicinal plants against Pneumoconiosis using *in silico* studies. The 3D structure of phytochemicals was obtained using IMPPAT and PubChem database. The Lipinski rule of five for all the phytochemicals was tested using Swiss ADME. The sequence of the target protein was modeled using Swiss-Model and evaluated using Ramachandran plot. The docking studies were performed using PyRx and the results were analyzed using Discovery Studio 2021. From the results, the phytochemicals 7-Deacetyl-7-benzoylgedunin, Kulactone and Decane-1,10-diyl bis(4-methylbenzene-1-sulfonate) showed very good binding affinity like -8.2, -8.1 and -7.9 Kcal/mol, respectively. Toxicity studies were done for the best-interacted phytochemicals and the results showed that the compounds had very less toxicity. Hence, the present study concludes that 7-Deacetyl-7-benzoylgedunin, Kulactone and Decane-1,10-diyl bis(4-methylbenzene-1-sulfonate) from *Azadirachta indica* and may have a potential ability in the treatment of Pneumoconiosis.





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Keywords: Pneumoconiosis, Phytocompounds, PyRx, Discovery Studio, Molecular Docking, ADMET analysis.

INTRODUCTION

A category of occupational lung infections characterized by diffuse lung tissue fibrosis is termed as Pneumoconiosis. Long term inhalation and deposition of infectious mineral dust into the lungs during work related activities is the main reason for Pneumoconiosis[1-4]. Among the occupational diseases in the world, Pneumoconiosis is the most dangerous one. It occurs mainly due to the chronic inhalation of mineral dusts, particularly silica and asbestos[5,6].As the patient is exposed the dust for an extended period of time, the lungs are unable to expel the dust from the alveoli and it accrues in the lungs, causing inflammation, which is called fibrosis and in the critical cases it is termed as necrosis[7]. Pneumoconiosis is a term that refers to a set of interstitial lung infection by inhaling mineral dust and resulting in lung dysfunction[8].The majority of this dust is made up of inorganic particles like free silica dust, asbestos fibres, coal mine dust, and mixed silicate dust. The condition's pathogenic features include chronic pulmonary inflammation and fibrosis[9].Lung fibrosis causes pneumoconiosis, which is aggravated by inflammation[10]. As a result of the use of unique materials (e.g., silica nanoparticles, sandblast, and artificial stone), pneumoconiosis has recently appeared in both old and new sectors (for example, biomedical applications, denim jeans production, and jewellery polishing)[11].The 1.3 billion people who reside in India live across 29 states and seven union territories, with many of them having populations higher than many countries. Climate, economy, and demographics can all have a significant impact on respiratory health[12]. Despite the fact that the global prevalence of pneumoconiosis has been declining since 2015, there are still a considerable number of patients, according to the Global Burden of Disease study[13-15].More than 60,000 new cases of pneumoconiosis were recorded in 2017, affecting an estimated 527,500 persons worldwide[16].In latest days, patient morbidity from pneumoconiosis has been significant[13-16].Since 2015, there have been over 21,000 deaths every year.

After lung transplant, sufferers with silicosis have a three-year survivability rate of up to 76%[17]and have a low average life expectancy of between 6 to 7 years[18].Silicosis is predicted to affect 6.2-34% of mica miners, 4.1 percent of manganese miners, 30.4 percent of lead and zinc miners, 9.3% of coal miners, 27.2 percent of iron forge workers, and 55 percent of slate pencil workers in India[19]. Many cases are likely undiagnosed and unreported in other less developed nations, particularly those with insufficient data system. As a result, identifying the real figure of pneumoconiosis cases is challenging. Furthermore, many employees are afraid to agree to diagnostic procedures, even if they are showing symptoms, because a finding of pneumoconiosis could result in loss of employment[20]. The simple and massive forms of CWP (Coal Worker's Pneumoconiosis) have both been described. Simple CWP is characterised by diffuse nodular opacities[21] and is usually asymptomatic. However, it can progress to progressive massive fibrosis[22](which appears as large masses of dense fibrosis) and cause respiratory insufficiency and secondary cardiac complications[23].Shortness of breath, chronic cough, and black sputum are common symptoms, which progress to clinically significant respiratory dysfunction, pulmonary hypertension, and heart issues with time[23,24]. The lungs are unable to remove insoluble silica, which stimulates macrophages and damages the pulmonary parenchyma over time, leads to chronic inflammation, the formation of silicotic nodules, and progressive fibrosis[25].The rapid progression of accelerated silicosis has been linked to long-term inhalation of high concentrations of RCS (Respirable Crystalline Silica) during sandblasting and AS (Artificial Stones) processing [26-30].It is usually observed in young employees, which means that patients may experience severe symptoms and die at an early age, which is a matter for common concern[18]. Pneumoconiosis is a lung illness that is gradual and permanent, however it can be prevented[31,32].It appeasements personal health and has the potential to harm families[33].Pneumoconiosis is currently treated with no specific medications or other approaches[34].Comprehensive therapies, such as fitness training, education and behavioural modification, and pulmonary rehabilitation (PR), are commonly employed in the treatment of respiratory disorders and can effectively provide long-term functional improvement and reduced clinical care needs[35-40]. End-stage pneumoconiosis can only be treated through lung transplantation[17].The patients normally utilized clinical signs, such as cough, chest



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pains, and breathing difficulty, are the primary focus of integrated therapy. In addition, addressing pneumoconiosis-related disorders (such as respiratory infections, tuberculosis, chronic obstructive pulmonary disease, and pneumothorax) and enabling patients to engage in regenerative exercises may help improve functional ability and relieve certain difficulties [37,41]. Moreover, because of a scarcity of promising therapeutic sites, there are no effectual medications. Diverse anti-inflammatory and anti-fibrotic medications are the most generally utilized corticosteroids, which invariably cause adverse side effects such as TB infection, osteonecrosis, and gastrointestinal symptoms during long-term therapeutic application [42-44]. Resveratrol has been proven in several studies to reduce oxidative stress, diminish free radicals like reactive oxygen species (ROS), and regulate inflammatory processes in persons with lung problems [45]. Currently, Nintedanib, Pirfenidone, Ambroxol were used as a synthetic drug for the treatment of Pneumoconiosis [46,47]. Caveolin-1 (Cav-1) is a caveolae-specific functional protein that is abundant in the lungs [48]. Cav-1 is a protein that controls lung fibrosis and inflammation. Cav-1 loss exacerbated cellular proliferation and collagen deposition [49,50] in the lungs of bleomycin-induced mice and radiation-induced rats. Cav-1 reduced inflammatory cell infiltration and inflammatory factor release in the lungs of mice given lipopolysaccharide (LPS). Cav-1 also suppressed macrophage activation through a variety of mechanisms [51,52]. Spirulina, a blue green alga, has been determined to be the most effective and long-lasting treatment for Silicosis.

The dietary and medicinal benefits of spirulina are widely documented. It is the richest and most comprehensive source of nourishment found in nature. Spirulina has a high level of antioxidant activity, which is mostly owing to the presence of phenolic and flavonoid compounds in it. Spirulina was found to be beneficial in induced silicosis rat models in a scientific study [53]. Chinese herbal kombucha formulations can help to expel silica dust from the lungs and Inhaling could be a promising new medicine for silicosis as well as other pneumoconiosis conditions. By fermenting extracts of several plants with a kombucha culture, Chinese herbal kombucha preparations can be prepared. Licorice, *Siratiagrosvenori*, mangosteen, and chrysanthemum are just a few examples of plants and herbs that can be utilised for this [54]. Licorice, also known as *Glycyrrhiza glabra* (Fabaceae), is a herbaceous perennial that is often used as a flavouring agent in meals and medicinal cures for centuries. Licorice root has been used to treat cough from olden history all across the world. Glycyrrhizin, glycyrrhetic acid, flavonoids, isoflavonoids, and chalcones are among the active chemicals found in it. The major active ingredients, glycyrrhizin and glycyrrhetic acid, are powerful inhibitors of cortisol metabolism because of having steroid-like structures. This plant's root has been used to treat coughs, colds, asthma, and COPD [55]. Glycyrrhizin is a triterpene glycoside that is derived from the plant *Glycyrrhiza glabra*. In vitro and in vivo, isoliquiritigenin, a flavonoid isolated from the roots of *G. glabra*, relaxing the tracheal smooth muscle of guinea pigs. In Asia and the Pacific islands, *Piper longum* (family Piperaceae) is utilised as a traditional medicine. *P. longum* is a well-known therapy for tuberculosis and respiratory problems [56]. In the present study, the Indian medicinal plants such as *Allium sativum*, *Azadirachta indica*, *Piper betle* [57], *Curcuma longa*, *Glycyrrhiza glabra* [58], *Adhatoda zeylanica*, *Ocimum tenuiflorum*, *Piper longum* [59], *Piper nigrum*, *Solanum virginianum* were taken to find the potential phytochemicals for treating Pneumoconiosis.

MATERIALS AND METHODS

Ligand selection

Using literature & IMPPAT database [60], around 530 phytochemical compounds were selected from the different Indian medicinal plants like *Allium sativum*, *Azadirachta indica*, *Piper betle* [57], *Curcuma longa*, *Glycyrrhiza glabra* [58], *Adhatoda zeylanica*, *Ocimum tenuiflorum*, *Piper longum* [59], *Piper nigrum*, *Solanum virginianum* for treating Pneumoconiosis. The 3D structure of phytochemical compounds was retrieved from the PubChem database [61] and using SwissADME [62] they were subjected to test Lipinski Rule of Five. From the results, 484 compounds obeyed Lipinski Rule of Five and these compounds were taken for further study.





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Target protein selection

The target protein Caveolin-1 belongs to Cav1 gene for Pneumoconiosis was found in the literature[63]. The 3D structure of this target protein was obtained from the Uniprot database[64] as a modelled protein. The UniProt ID for this target protein was noted. Further, the modelled structure was evaluated using SAVES v6.0 online server[65] and Ramachandran plot was taken using this server.

Docking studies

Docking studies for the modelled target protein Caveolin-1 and the phytochemicals (ligands) were done using PyRx 0.8 software[66]. The target protein was further prepared for docking studies using this software. All the ligands were uploaded using Open Babel option in the PyRx 0.8. The grid was generated and the docking studies were performed using Vina wizard option in the PyRx 0.8. The values of binding affinity were saved in XL file. The results were analyzed using Discovery Studio 2021 and the 2D and 3D docked images were taken. In the results, the lowest binding affinity indicates good result.

ADMET and CYP properties:

ADMET and CYP properties were tested for all the best-interacted phytochemicals using Swiss ADME[62]. Lipinski, BBB (Blood - Brain Barrier), HIA (Human Intestinal Absorption), PGP (P-glycoprotein), XLogP3, TPSA (Topological Polar Surface Area), LogS, Fraction Csp3, Rotatable bonds, CYP enzyme inhibitor properties, Skin permeation and Bioavailability score were evaluated for all the best-interacted compounds.

RESULTS AND DISCUSSION

Ligand and Target Protein selection:

The 3D structure of ligands (phytochemicals) was retrieved from the PubChem database. The 3D structure of the modelled target protein Caveolin-1 was obtained from the Uniprot database and its UniProt ID is Q03135. Further, the Ramachandran plot was taken using SAVES v6.0 online server to evaluate the modelled 3D structure. In the results, 86.9 % amino acid residues are located in the most favoured regions and it confirms that the predicted model is good. The 3D structure of the modelled target protein and the Ramachandran plot are shown in figure 1 and 2.

Docking studies

Docking studies were done for the phytochemicals, from the different Indian medicinal plants and the target protein Caveolin-1 using PyRx 0.8 software to find the potential drug candidate for Pneumoconiosis. For this, 484 phytochemicals which has passed Lipinski Rule of Five were interacted with the target protein using this software. The results were analysed using this software and Discovery Studio 2021 and binding affinity value was noted. In which, 10 compounds showed very good results with the target protein. Further, the Synthetic drugs Nintedanib, Resveratrol, Pirfenidone and Ambroxol were also taken to find the interaction with the target protein. The docking results of phytochemicals and the synthetic drugs are shown in Table 1 and Table 2 respectively. The 2D and 3D interactions of the phytochemicals and the Synthetic drugs with the target protein are shown in Figures 3-10. From the results (Table 1), among other compounds, 10 compounds showed very good results with the target protein. Of which, the phytochemical 7-Deacetyl-7-benzoylgedunin showed very good binding affinity (-8.2 Kcal/mol) with the amino acid residues ARG 54, ASN 60 and TYR 100 of the target protein. The phytochemical Kulactone also gave very good binding affinity of -8.1 Kcal/mol with the amino acid residues TYR 100, LEU 103, LYS 96 and PHE 92. The binding affinity -7.9 Kcal/mol was observed between the phytochemical Decane-1,10-diyl bis(4-methylbenzene-1-sulfonate) and the amino acid residues ASP 61, LYS 96, ASP 55, ARG 54 and TYR100 of target protein. Among the ten compounds, the lowest binding affinity (-7.5 Kcal/mol) was observed between the phytochemical Diosgenin and the amino acid residues SER 88 and PHE 92 of target protein. From the results of Table 2, the binding affinity of the Synthetic drugs Ambroxol with the target protein was -4.6 Kcal/mol and the interacted the amino acid residues were PHE107, LEU 103, TYR 100, Pirfenidone with the target protein was -4.9 Kcal/mol and the interacted the amino acid residues were TYR 100, LYS 96, TYR 97, Resveratrol with the target protein was -5.2 Kcal/mol and the interacted the





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amino acid residues were LEU 103, TYR 100, LYS 96. Nintedanib with the target protein was -7.1 Kcal/mol and the interacted amino acid residues were LEU 103, TYR 100, LYS 96. Besides, in the present study, all the phytocompounds showed very good binding affinity when compared to all the 4 synthetic drugs. Further, Previous study found that the compounds like Dioscin, Astragaloside IV, Kaempferol, Tanshinone IIA, Dihydrotanshinone I from traditional Chinese herbal extracts showed the potential ability to treat silicosis in mouse and rat model.[67-71] *Azadirachta indica*, *Curcuma longa*, *Ocimum sanctum*, *Piper betle* and *Allium sativum* were discovered to have potential for treating Bronchitis, Cough, and Asthma in a previous study[57]. The medicinal plants such as *Solanum surattense*, *Adhatoda vasica*, *Glycyrrhiza glabra*, *Ocimum sanctum*, *Curcuma longa* have Bronchodilator, Anti-allergen, Anti-asthmatic, Anti-inflammatory, Immunomodulator, Anti-oxidant properties[58]. *Spirulina*, a blue green algae, has been determined to be the most effective and long-lasting treatment for silicosis[72]. *P. longum* is a well-known therapy for tuberculosis and respiratory infections[56]. The fruits and roots of this plant have been used to treat asthma in children[73,74] reported that Chinese herbal kombucha remedies can aid in the removal of silica dust from lung tissue. Inhaling Chinese herbal kombucha could be a novel therapy option for silicosis and other pneumoconiosis illnesses. Similarly, in the present study, the phytocompound 7-Deacetyl-7-benzoylgedunin, Kulactone and Decane-1,10-diyl bis(4-methylbenzene-1-sulfonate) from *Azadirachta indica* showed the highest binding affinity with the target protein Caveolin-1 and it concludes that they may have a potential ability for treating Pneumoconiosis.

ADMET and CYP Properties

In the present study, ADMET properties were tested for the best interacted phytocompounds and Synthetic drugs Nintedanib, Resveratrol, Pirfenidone and Ambroxol using SwissADME and the results were tabulated (table 3). From the results, all the best interacted phytocompounds and Synthetic drugs obey Lipinski rule of five. Most of the compounds did not cross Blood – Brain Barrier (BBB) and had high Intestinal Absorption (HIA). Many phytocompounds predicted not to be effluated from the CNS by P-glycoprotein. Similarly, few phytocompounds predicted to be effluated from the CNS by P-glycoprotein. Among the 10 compounds, XLogP3 value of only 2 compounds like 21alpha-Hydroxyisoglabrolide and 6-Acetylnimbandiol were within the range. TPSA (Topological Polar Surface Area) and Log S value of the most of the compounds were within the limit. In the Fraction Csp3 value of all the compounds, only 2 compounds (Resveratrol and Pirfenidone) were less than 0.25 and the value of other compounds were above this limit. Rotatable bonds for the most of the compounds were within the limit but the Rotatable bond value of one phytocompound (Decane-1,10-diyl bis(4-methylbenzene-1-sulfonate)) was above the limit. From the results of the Boiled Egg image of the phytocompounds (Figure 11), the compounds Diosgenin (PubChem ID: 99474) and Hispaglabridin B (PubChem ID:15228661) are located in the Egg-yolk region, which means the compounds are passively absorbed by the gastrointestinal tract and can also permeate through the blood-brain barrier. And the compounds 7-Deacetyl-7-benzoylgedunin (PubChem ID:52952112), 21alpha-Hydroxyisoglabrolide (PubChem ID:101280184) and 6-Acetylnimbandiol (PubChem ID:52952216) are located in the Egg-white region, which means they are passively absorbed by the gastrointestinal tract but cannot permeate through the blood brain barrier. Moreover, the compounds Diosgenin (PubChem CID: 99474), 6-Acetylnimbandiol (PubChem CID:52952216), Kulactone (PubChem CID:15560423), Ursolic acid (PubChem CID:64945) and Sitosteryl glucoside (PubChem CID:70699351) are predicted not to be effluated from the central nervous system by the P-glycoprotein. And the compounds Hispaglabridin B (PubChem CID:15228661), 21alpha-Hydroxyisoglabrolide (PubChem CID:101280184), 7-Deacetyl-7-benzoylgedunin (PubChem CID:52952112) and Decane-1,10-diyl bis(4-methylbenzene-1-sulfonate) (PubChem CID:298060) are predicted to be effluated from the central nervous system by the P-glycoprotein. In the results of CYP properties (table 4), most of the compounds does not inhibit the CYP enzymes and does not give any adverse reactions. But, the compound Kulactone inhibits CYP2C9, Decane-1,10-diyl bis(4-methylbenzene-1-sulfonate) inhibits CYP2C19, CYP2C9 and CYP3A4 and Hispaglabridin B inhibits all the CYP enzymes respectively. The value of log Kp (Skin Permeant) is good for all compounds and A Bioavailability Score (ABS) is good for all the compounds.





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CONCLUSION

In the present study, the phytochemicals from the different Indian medicinal plants and the target protein Caveolin-1 were subjected for *in silico* docking analysis to find the potential phytochemicals for treating Pneumoconiosis. From the results, 30 compounds showed better results than the Synthetic drugs Nintedanib, Resveratrol, Pirfenidone, and Ambroxol. Among them, 10 compounds showed very good binding affinity with the target protein. Of which, the phytochemicals 7-Deacetyl-7-benzoylgedunin, Kulactone and Decane-1,10-diyl bis(4-methylbenzene-1-sulfonate) showed the highest binding with the target protein Caveolin-1. Toxicity studies were also done for the 10 best-interacted phytochemicals and the results showed that the compounds had very less toxicity. Hence, the present study concludes that 7-Deacetyl-7-benzoylgedunin, Kulactone and Decane-1,10-diyl bis(4-methylbenzene-1-sulfonate) from *Azadirachta indica* and may have a potential ability in the treatment of Pneumoconiosis.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

AUTHOR CONTRIBUTION

MS and DP both were carried out the work. AL wrote the manuscript. VU analyze and interpret the results and PR design and guided the entire work.

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REFERENCES

1. Cullinan P, Reid P. Pneumoconiosis. *Prim Care Resp J*. 2013;22(2):249-52.
2. Mlika M, Adigun R, Gossman WG. Silicosis (coal worker pneumoconiosis).
3. Castranova V, Vallyathan V. Silicosis and coal workers' pneumoconiosis. *Environ health persp*. 2000;108(suppl 4):675-84.
4. Leung CC, Yu IT, Chen W. Silicosis. *Lancet*. 2012;379(9830):2008-18.
5. Greenberg MI, Waksman J, Curtis J. Silicosis: a review. *Dis Mon*. 2007;53(8):394-416.
6. Seaman DM, Meyer CA, Kanne JP. Occupational and environmental lung disease. *Clin chest med*. 2015;36(2):249-68.
7. Chong S, Lee KS, Chung MJ, Han J, Kwon OJ, Kim TS. Pneumoconiosis: comparison of imaging and pathologic findings. *Radiographics*. 2006;26(1):59-77.
8. Austin ED, Loyd JE. The genetics of pulmonary arterial hypertension. *Circ res*. 2014;115(1):189-202.
9. Perret JL, Plush B, Lachapelle P, Hinks TS, Walter C, Clarke P, Irving L, Brady P, Dharmage SC, Stewart A. Coal mine dust lung disease in the modern era. *Respirology*. 2017;22(4):662-70.
10. Shen CH, Chen HJ, Lin TY, Huang WY, Li TC, Kao CH. Association between pneumoconiosis and pulmonary emboli. *Thromb haemostasis*. 2015;113(05):952-7.
11. Ya LU, Qi XM, Pang JL, Jing WA, Chen WA. Omics approaches for exploring pneumoconiosis: a review. *Biomedical and Environmental Sciences*. 2021;34(1):71-82.
12. Dandona L, Dandona R, Kumar GA, Shukla DK, Paul VK, Balakrishnan K, Prabhakaran D, Tandon N, Salvi S, Dash AP, Nandakumar A. Nations within a nation: variations in epidemiological transition across the states of India, 1990–2016 in the Global Burden of Disease Study. *Lancet*. 2017; 390(10111):2437-60.





Subasri et al.,

13. Abubakar II, Tillmann T, Banerjee A. Global, regional, and national age-sex specific all-cause and cause-specific mortality for 240 causes of death, 1990–2013: a systematic analysis for the Global Burden of Disease Study 2013. *Lancet*. 2015;385(9963):117-71.
14. Vos T, Allen C, Arora M, Barber RM, Bhutta ZA, Brown A, Carter A, Casey DC, Charlson FJ, Chen AZ, Coggeshall M. Global, regional, and national incidence, prevalence, and years lived with disability for 310 diseases and injuries, 1990–2015: a systematic analysis for the Global Burden of Disease Study 2015. *Lancet*. 2016;388(10053):1545-602.
15. Naghavi M, Abajobir AA, Abbafati C, Abbas KM, Abd-Allah F, Abera SF, Aboyans V, Adetokunboh O, Afshin A, Agrawal A, Ahmadi A. Global, regional, and national age-sex specific mortality for 264 causes of death, 1980–2016: a systematic analysis for the Global Burden of Disease Study 2016. *Lancet*. 2017;390(10100):1151-210.
16. Kiadaliri AA. Global, regional, and national incidence, prevalence, and years lived with disability for 354 diseases and injuries for 195 countries and territories, 1990–2017: a systematic analysis for the Global Burden of Disease Study 2017. *Lancet*. 2018;392(10159):1789-858.
17. Rosengarten D, Fox BD, Fireman E, Blanc PD, Rusanov V, Fruchter O, Raviv Y, Shtraichman O, Saute M, Kramer MR. Survival following lung transplantation for artificial stone silicosis relative to idiopathic pulmonary fibrosis. *Am J Ind Med*. 2017;60(3):248-54.
18. Hoy RF, Chambers DC. Silica-related diseases in the modern world. *Allergy*. 2020;75(11):2805-17.
19. Munjal YP, Sharm SK. API Textbook of Medicine, Two Volume Set. JP Medical Ltd; 2012.
20. Voelker R. Black lung resurgence raises new challenges for coal country physicians. *Jama*. 2019;321(1):17-9.
21. Vallyathan V, Brower PS, Green FH, Attfield MD. Radiographic and pathologic correlation of coal workers' pneumoconiosis. *Am j resp crit care*. 1996;154(3):741-8.
22. Silicosis. Available at: <https://radiopaedia.org/articles/silicosis>. Accessed on 19th April.
23. David GL, Zeldin DC. Coal Workers' Pneumoconiosis in Encyclopedia of Molecular Mechanisms of Disease. *Springer*; 373-374.
24. Chong S, Lee KS, Chung MJ, Han J, Kwon OJ, Kim TS. Pneumoconiosis: comparison of imaging and pathologic findings. *Radiographics*. 2006;26(1):59-77.
25. Franklin BS, Mangan MS, Latz E. Crystal formation in inflammation. *Annu rev immunol*. 2016;34:173-202.
26. Leso V, Fontana L, Romano R, Gervetti P, Iavicoli I. Artificial stone associated silicosis: a systematic review. *Int j environ res pub he*. 2019;16(4):568.
27. Akgun M, Araz O, Ucar EY, Karaman A, Alper F, Gorguner M, Kreiss K. Silicosis appears inevitable among former denim sandblasters: a 4-year follow-up study. *Chest*. 2015;148(3):647-54.
28. Akgun M, Araz O, Akkurt I, Eroglu A, Alper F, Saglam L, Mirici A, Gorguner M, Nemery B. An epidemic of silicosis among former denim sandblasters. *Eur Respir J*. 2008;32(5):1295-303.
29. Akgun M, Ergun B. Silicosis in Turkey: is it an endless nightmare or is there still hope?. *Turk Thorac J*. 2018;19(2):89.
30. Wu N, Xue C, Yu S, Ye Q. Artificial stone-associated silicosis in China: a prospective comparison with natural stone-associated silicosis. *Respirology*. 2020;25(5):518-24.
31. Zosky GR, Hoy RF, Silverstone EJ, Brims FJ, Miles S, Johnson AR, Gibson PG, Yates DH. Coal workers' pneumoconiosis: an Australian perspective. *Med J Australia*. 2016;204(11):414-8.
32. Yen CM, Lin CL, Lin MC, Chen HY, Lu NH, Kao CH. Pneumoconiosis increases the risk of congestive heart failure: a nationwide population-based cohort study. *Medicine*. 2016;95(25).
33. Shen CH, Chen HJ, Lin TY, Huang WY, Li TC, Kao CH. Association between pneumoconiosis and pulmonary emboli. *Thromb haemostasis*. 2015;113(05):952-7.
34. Liang YX, Wong O, Fu H, Hu TX, Xue SZ. The economic burden of pneumoconiosis in China. *Occup Environ Med*. 2003;60(6):383-4.
35. Ochmann U, Kotschy-Lang N, Raab W, Kellberger J, Nowak D, Jörres RA. Long-term efficacy of pulmonary rehabilitation in patients with occupational respiratory diseases. *Respiration*. 2012;84(5):396-405.
36. Tsang EW, Kwok H, Chan AK, Choo KL, Chan KS, Lau KS, Chan CC. Outcomes of community-based and home-based pulmonary rehabilitation for pneumoconiosis patients: a retrospective study. *BMC pulm med*. 2018;18(1):1-9.





Subasri et al.,

37. Dowman L, Hill CJ, May A, Holland AE. Pulmonary rehabilitation for interstitial lung disease. *Cochrane Db Syst Rev.* 2021(2).
38. Jenkins AR, Gowler H, Curtis F, Holden NS, Bridle C, Jones AW. Efficacy of supervised maintenance exercise following pulmonary rehabilitation on health care use: a systematic review and meta-analysis. *Int j chronic obstruct.* 2018;13:257.
39. Ryrso CK, Godtfredsen NS, Kofod LM, Lavesen M, Mogensen L, Tobberup R, Farver-Vestergaard I, Callesen HE, Tendal B, Lange P, Iepsen UW. Lower mortality after early supervised pulmonary rehabilitation following COPD-exacerbations: a systematic review and meta-analysis. *BMC pulm med.* 2018;18(1):1-8.
40. Nici L, ZuWallack RL. Pulmonary rehabilitation: definition, concept, and history. *Clin chest med.* 2014;35(2):279-82.
41. Cockcroft AE, Saunders MJ, Berry G. Randomised controlled trial of rehabilitation in chronic respiratory disability. *Thorax.* 1981 Mar 1;36(3):200-3.
42. McKeever T, Harrison TW, Hubbard R, Shaw D. Inhaled corticosteroids and the risk of pneumonia in people with asthma: a case-control study. *Chest.* 2013;144(6):1788-94.
43. Schreiber MP, Colantuoni E, Bienvenu OJ, Neufeld KJ, Chen KF, Shanholtz C, Mendez-Tellez PA, Needham DM. Corticosteroids and transition to delirium in patients with acute lung injury. *Crit care med.* 2014 Jun;42(6):1480.
44. Painter RC, Roseboom TJ, de Rooij SR. Long-term effects of prenatal stress and glucocorticoid exposure. *Birth Defects Research Part C: Embryo Today: Reviews.* 2012;96(4):315-24.
45. Wu S, Huang J. Resveratrol alleviates Staphylococcus aureus pneumonia by inhibition of the NLRP3 inflammasome. *Exp Ther Med.* 2017;14(6):6099-104.
46. NCT, 2022a. Available online: <https://clinicaltrials.gov/ct2/show/NCT04161014> accessed on 7th April 2022.
47. Medindia, 2022. Available online: <https://www.medindia.net/drugs/medical-condition/pneumoconiosis.htm> accessed on 04th May 2022.
48. Sanon, V.P., Sawaki, D., Mjaatvedt, C.H. and Jourdan-Le Saux, C., 2011. Myocardial tissue caveolae. *Compr Physiol*, 5(2), pp.871-886.
49. Gvaramia D, Blaauboer ME, Hanemaaijer R, Everts V. Role of caveolin-1 in fibrotic diseases. *Matrix Biol.* 2013 Aug 8;32(6):307-15.
50. Kulshrestha R, Singh H, Pandey A, Mehta A, Bhardwaj S, Jaggi AS. Caveolin-1 as a critical component in the pathogenesis of lung fibrosis of different etiology: evidences and mechanisms. *Exp mol pathol.* 2019;111:104315.
51. Cai L, Yi F, Dai Z, Huang X, Zhao YD, Mirza MK, Xu J, Vogel SM, Zhao YY. Loss of caveolin-1 and adiponectin induces severe inflammatory lung injury following LPS challenge through excessive oxidative/nitrative stress. *Am J Physiol-Lung C.* 2014;306(6):L566-73.
52. Liu J, Huang X, Hu S, He H, Meng Z. Dexmedetomidine attenuates lipopolysaccharide induced acute lung injury in rats by inhibition of caveolin-1 downstream signaling. *Biomed Pharmacother.* 2019;118:109314.
53. Zhongxing ZH, Li YA, Kaiguo WU. Effect of spirulina on antioxidation of experimental silicosis of rat. *中国公共卫生.* 2005;21(1):8-9.
54. Fu NF, Luo CH, Wu JC, Zheng YY, Gan YJ, Ling JA, Liang HQ, Liang DY, Xie J, Chen XQ, Li XJ. Clearance of free silica in rat lungs by spraying with chinese herbal kombucha. *Evid-Based Compl Alt.* 2013;2013.
55. Ram A, Balachandar S, Vijayananth P, Singh VP. Medicinal plants useful for treating chronic obstructive pulmonary disease (COPD): current status and future perspectives. *Fitoterapia.* 2011;82(2):141-51.
56. Singh YN. Kava: an overview. *J ethnopharmacol.* 1992 Aug 1;37(1):13-45.
57. Sundaram SS, Suresh K. Medicinal plants used for the treatment of respiratory diseases in Alagar Hills of Madurai district, Tamil Nadu, India.
58. Baheti SR, Kumar S. APPROACH OF AYURVEDA AND YOGA IN THE MANAGEMENT OF OCCUPATIONAL LUNG DISEASES.
59. Dwivedi SD, Dwivedi A. Herbal remedies for respiratory diseases among the Natives of Madhya Pradesh, India. *Am J Life Sci Res.* 2015;3(2).





Subasri et al.,

60. Mohanraj, K., Karthikeyan, B.S., Vivek-Ananth, R.P., Chand, R.P., Aparna, S.R., Mangalapandi, P. and Samal, A., 2018. IMPPAT: a curated database of Indian medicinal plants, phytochemistry and therapeutics. *Sci rep*, 8(1), pp.1-17.
61. Kim S, Chen J, Cheng T, Gindulyte A, He J, He S, Li Q, Shoemaker BA, Thiessen PA, Yu B, Zaslavsky L. PubChem in 2021: new data content and improved webinterfaces. *Nucleic acids res.* 2021; 49(D1):D1388-95.
62. Daina A, Michielin O, Zoete V. SwissADME: a free web tool to evaluate pharmacokinetics, drug-likeness and medicinal chemistry friendliness of smallmolecules. *Sci rep.* 2017; 7(1):1-3.
63. He R, Yuan X, Lv X, Liu Q, Tao L, Meng J. Caveolin-1 negatively regulates inflammation and fibrosis in silicosis. *J Cell Mol Med.* 2022;26(1):99-107.
64. UniProt (2022). <https://www.uniprot.org/uniprot/P61826> Accessed on 13th April2022.
65. SAVES (2022). <https://saves.mbi.ucla.edu/> Accessed on 24th April 2022.
66. Trott, O. and Olson, A.J., 2010. AutoDockVina: improving the speed and accuracy of docking with a new scoring function, efficient optimization, and multithreading. *Jcomput chem*, 31(2), pp.455-461.
67. Du S, Li C, Lu Y, Lei X, Zhang Y, Li S, Liu F, Chen Y, Weng D, Chen J. Dioscin alleviates crystalline silica-induced pulmonary inflammation and fibrosis through promoting alveolar macrophage autophagy. *Theranostics.* 2019;9(7):1878.
68. Li N, Feng F, Wu K, Zhang H, Zhang W, Wang W. Inhibitory effects of astragaloside IV on silica-induced pulmonary fibrosis via inactivating TGF- β 1/Smad3 signaling. *Biomed Pharmacother.* 2019;119:109387.
69. Liu H, Yu H, Cao Z, Gu J, Pei L, Jia M, Su M. Kaempferol modulates autophagy and alleviates silica-induced pulmonary fibrosis. *DNA cell biol.* 2019;38(12):1418-26.
70. Feng F, Cheng P, Zhang H, Li N, Qi Y, Wang H, Wang Y, Wang W. The protective role of tanshinone IIA in silicosis rat model via TGF- β 1/Smad signaling suppression, NOX4 inhibition and Nrf2/ARE signaling activation. *Drug Des Dev Ther.* 2019;13:4275.
71. Zhang Y, Li C, Li S, Lu Y, Du S, Zeng X, Chen X, Chen J. Dihydrotanshinone I alleviates crystalline silica-induced pulmonary inflammation by regulation of the Th immune response and inhibition of STAT1/STAT3. *Mediat Inflamm.* 2019;2019.
72. Singh J, Parwani L. Spirulina: a new hope for silicosis. *J Nutr Health Food Eng.* 2018;8:214.
73. Dahanukar SA, Karandikar SM, Desai M. Efficacy of Piper longum in childhood asthma. *Indian drugs.* 1984; 21(9):384-8.
74. Fu NF, Luo CH, Wu JC, Zheng YY, Gan YJ, Ling JA, Liang HQ, Liang DY, Xie J, Chen XQ, Li XJ. Clearance of free silica in rat lungs by spraying with chinese herbal kombucha. *Evid-Based Compl Alt.* 2013;2013.

Table 1: Interaction of Phytochemicals with the Target Protein

S. No.	PubChem (CID)	Compound Name	Plant Name	Binding Affinity (Kcal/mol)	No. of Bonds	Interacting Residues	Bond Length (Å)
1.	52952112	7-Deacetyl-7-benzoylgedunin	<i>Azadirachta indica</i>	-8.2	3	ARG 54 ASN 60 TYR 100	5.43 2.02 3.87





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2.	15560423	Kulactone	<i>Azadirachta indica</i>	-8.1	4	TYR 100 LEU 103 LYS 96 PHE 92	4.92 4.76 5.24 3.04
3.	298060	Decane-1,10-diyl bis(4-methylbenzene-1-sulfonate)	<i>Azadirachta indica</i>	-7.9	7	ASP 61 LYS 96 LYS 96 ASP 55 ARG 54 ARG 54 TYR100	3.59 2.88 2.58 2.45 2.48 2.15 3.62
4.	65252	Obtusifoliol	<i>Azadirachta indica</i>	-7.9	3	ASP 61 LYS 96 TYR 100	2.46 4.01 3.81
5.	15228661	Hispaglabridin B	<i>Glycyrrhiza glabra</i>	-7.9	5	LYS 96 LYS 96 LYS 96 PHE 92 PHE 92	4.77 3.57 3.77 2.40 4.97
6.	101280184	21alpha-Hydroxyisoglabrolide	<i>Glycyrrhiza glabra</i>	-7.7	2	SER 104 GLY 108	2.75 3.68
7.	70699351	Sitosteryl glucoside	<i>Solanum virginianum</i>	-7.6	7	ASN 53 ASP 55 VAL 64 TYR 100 TYR 100 PHE 99 LYS 96	2.41 2.41 4.81 4.70 3.79 4.63 4.27
8.	64945	Ursolic acid	<i>Ocimum tenuiflorum</i>	-7.5	3	LYS 96 LYS 96 ASP 61	2.30 2.41 1.93
9.	52952216	6-Acetylnimbandiol	<i>Azadirachta indica</i>	-7.5	6	ASN 60 ASN 60 LYS 96 LYS 96 TYR 97 ARG 54	2.12 2.80 4.60 3.49 5.17 1.80





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10.	99474	Diosgenin	<i>Piper betle</i>	-7.5	2	SER 88 PHE 92	2.78 5.14
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Table 2: Interaction of Synthetic Drugs with the Target Protein

S.No.	PubChem (CID)	Compound Name	Compound Type	Binding Affinity (Kcal/mol)	No. of Bonds	Interacting Residues	Bond Length (Å)
1.	135423438	Nintedanib	Synthetic drug	-7.1	5	LEU 103 TYR 100 LYS 96 LYS 96 LYS 96	3.96 4.69 3.63 3.75 5.11
2.	445154	Resveratrol	Phytocompound	-5.2	3	LEU 103 TYR 100 LYS 96	4.76 5.51 1.96
3.	40632	Pirfenidone	Synthetic drug	-4.9	5	TYR 100 LYS 96 LYS 96 TYR 97 TYR 97	3.98 4.26 5.30 4.87 5.43
4.	2132	Ambroxol	Synthetic drug	-4.6	4	PHE 107 LEU 103 LEU 103 TYR 100	4.67 4.03 4.24 5.00

Table 3: ADMET Properties of Phytocompounds

S. No.	PubChem(CID)	Compound Name	Lipinski	BBB	HIA	PGP	XLOGP3	TPSA (Å)	LogS (ESOL)	Fracton Csp3	Rotatable Bonds
1	52952112	7-Deacetyl-7-benzoylgedunin	Yes	No	High	No	5.88	95.34	-6.86	0.55	4
2	15560423	Kulactone	Yes	No	Low	Yes	6.89	43.37	-6.79	0.80	3
3	298060	Decane-1,10-diyl bis(4-methylbenzene-1-sulfonate)	Yes	No	Low	No	6.51	103.50	-6.22	0.50	15
4	65252	Obtusifoliol	Yes	No	Low	NA	9.05	20.23	-7.86	0.87	5





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5	15228661	Hispaglabridin B	Yes	Yes	High	No	5.17	47.92	-5.76	0.36	1
6	101280184	21alpha-Hydroxyisoglabr olide	Yes	No	High	No	4.78	83.83	-5.86	0.87	0
7	70699351	Sitosteryl glucoside	Yes	No	Low	Yes	7.74	99.38	-7.70	0.94	9
8	64945	Ursolic acid	Yes	No	Low	Yes	7.34	57.53	-7.23	0.90	1
9	52952216	6- Acetylnimbandiol	Yes	No	High	Yes	1.44	112.2 7	-3.55	0.61	6
10	99474	Diosgenin	Yes	Yes	High	Yes	5.67	38.69	-5.98	0.93	0
Synthetic Drugs											
11	135423438	Nintedanib	Yes	No	High	No	4.30	101.4 7	-5.69	0.26	9
12	445154	Resveratrol	Yes	Yes	High	Yes	3.13	60.69	-3.62	0.00	2
13	40632	Pirfenidone	Yes	Yes	High	Yes	1.86	22.00	-2.73	0.08	1
14	2132	Ambroxol	Yes	Yes	High	No	2.64	58.25	-3.90	0.54	3

Note: Obey Lipinski: Yes means 0 violation & good, BBB (Blood - Brain Barrier): Yes means good, HIA (Human Intestinal Absorption): High means good, PGP- (Molecules predicted not to be effluated from the CNS by P-glycoprotein): Yes means good, Lipophilicity: XLOGP3 value between -0.7 and +5.0 means good, Polarity: TPSA between 20 and 130 Å² means good, Water Solubility (Log S scale: Insoluble < -10 < Poorly < -6 < Moderately < -4 < Soluble < -2 < Very < 0 < Highly): Log S value not higher than 6 means good, Saturation (Fraction Csp3): Fraction of carbons in the sp³ hybridization not less than 0.25 means good, and Flexibility (Rotatable bonds): No more than 9 rotatable bonds means good.





Table 4: Cytochrome P450 properties of phytochemicals

S. No.	PubChem (CID)	Compound Name	CYP1A2 inhibitor	CYP2C19 inhibitor	CYP2C9 inhibitor	CYP2D6 inhibitor	CYP3A4 inhibitor	Log K _p (Skin permeation) (cm/s)	A Bioavailability Score (ABS)
1	52952112	7-Deacetyl-7-benzoylgedunin	No	No	No	No	No	-5.45	0.55
2	15560423	Kulactone	No	No	Yes	No	No	-4.17	0.55
3	298060	Decane-1,10-diyl bis(4-methylbenzene-1-sulfonate)	No	Yes	Yes	No	Yes	-4.62	0.55
4	65252	Obtusifoliol	No	No	No	No	No	-2.48	0.55
5	15228661	Hispaglabridin B	Yes	Yes	Yes	Yes	Yes	-5.01	0.55
6	101280184	21alpha-Hydroxyisoglabrolide	No	No	No	No	No	-5.86	0.55
7	70699351	Sitosteryl glucoside	No	No	No	No	No	-4.32	0.55
8	64945	Ursolic acid	No	No	No	No	No	-3.87	0.85
9	52952216	6-Acetylnimbandiol	No	No	No	No	No	-8.32	0.55
10	99474	Diosgenin	No	No	No	No	No	-4.80	0.55
Synthetic Drugs									
11	135423438	Nintedanib	No	Yes	Yes	Yes	No	-6.54	0.55
12	445154	Resveratrol	Yes	No	Yes	No	Yes	-5.47	0.55
13	40632	Pirfenidone	Yes	No	No	No	No	-6.11	0.55
14	2132	Ambroxol	No	No	No	Yes	No	-6.73	0.55

Note: No means good, the compound does not inhibit the CYP450 enzymes and does not give any adverse reactions; Yes means the compound inhibits the CYP450 enzymes and gives unanticipated adverse reactions; The more negative the log K_p, the less skin permeant is the molecule; ABS 0.55 means it passes the rule of five & 0.17 means it fails the rule of five.



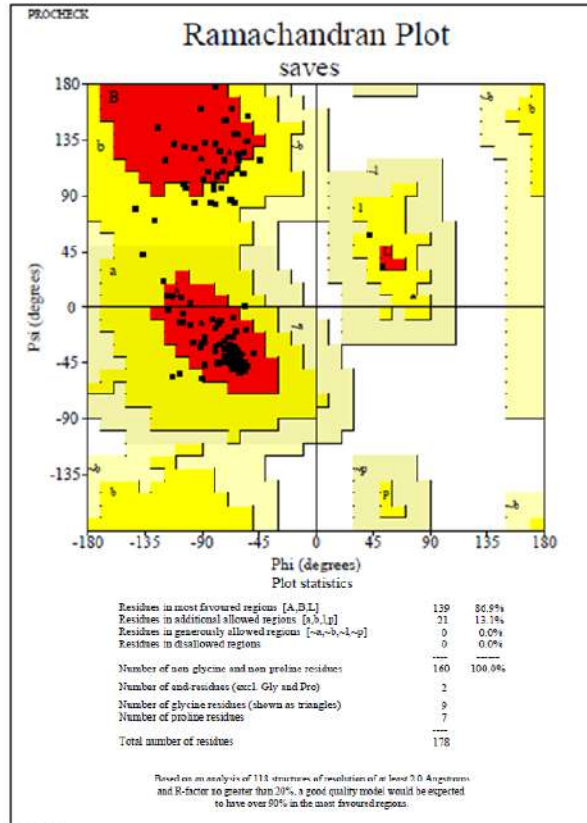
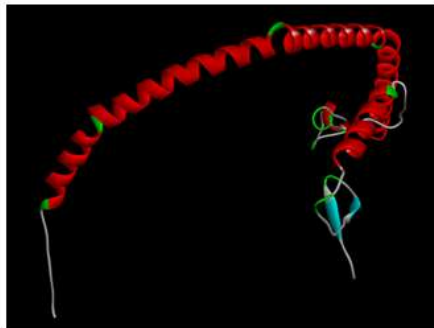


Figure 1: The 3D Structure of the modelled target protein Caveolin-1

Figure 2: Ramachandran plot for the 3D Structure of the modeled target protein Caveolin-1

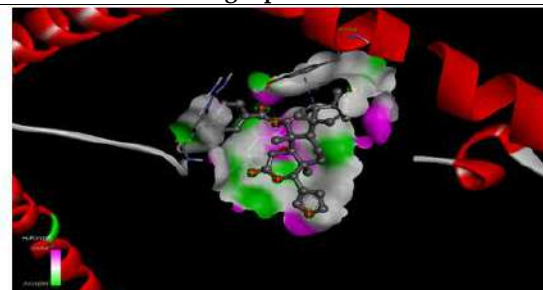
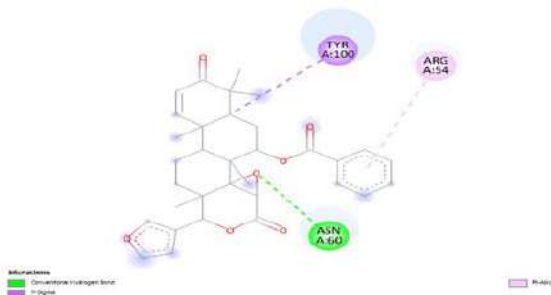


Figure 3: The 2D Interaction of Phytocompound 7-Deacetyl-7-benzoylgedunin with the Target Protein

Figure 4: The 3D Interaction of Phytocompound 7-Deacetyl-7-benzoylgedunin with the Target Protein





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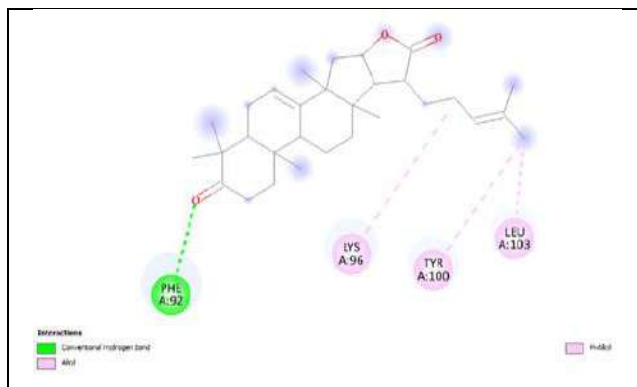


Figure 5: The 2D Interaction of Phytochemical Kulactone with the Target Protein

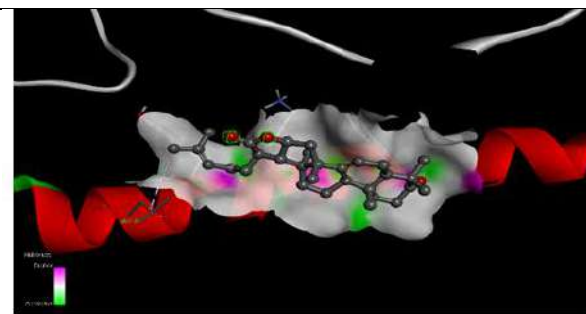


Figure 6: The 3D Interaction of Phytochemical Kulactone with the Target Protein

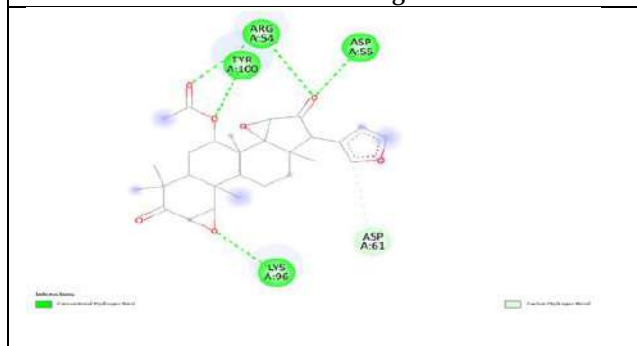


Figure 7: The 2D Interaction of Phytochemical Decane-1,10-diyl bis(4-methylbenzene-1-sulfonate) with the Target Protein

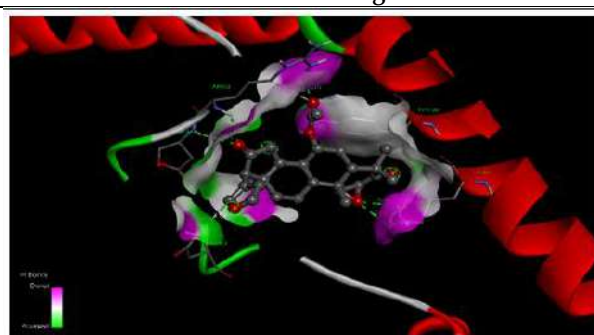


Figure 8: The 3D Interaction of Phytochemical Decane-1,10-diyl bis(4-methylbenzene-1-sulfonate) with the Target Protein

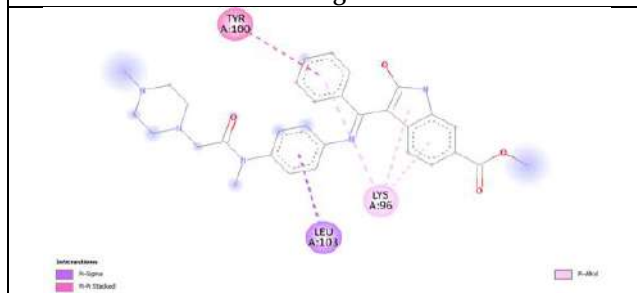


Figure 9: The 2D Interaction of Synthetic drug Nintedanib with the Target Protein

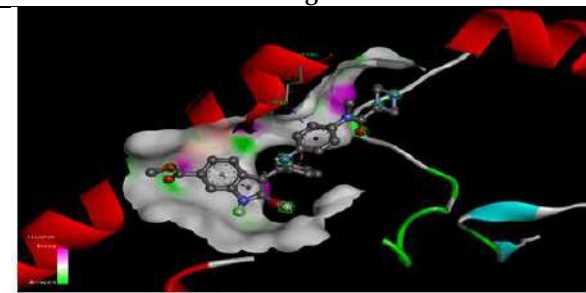


Figure 10: The 3D Interaction of Synthetic drug Nintedanib with the Target Protein





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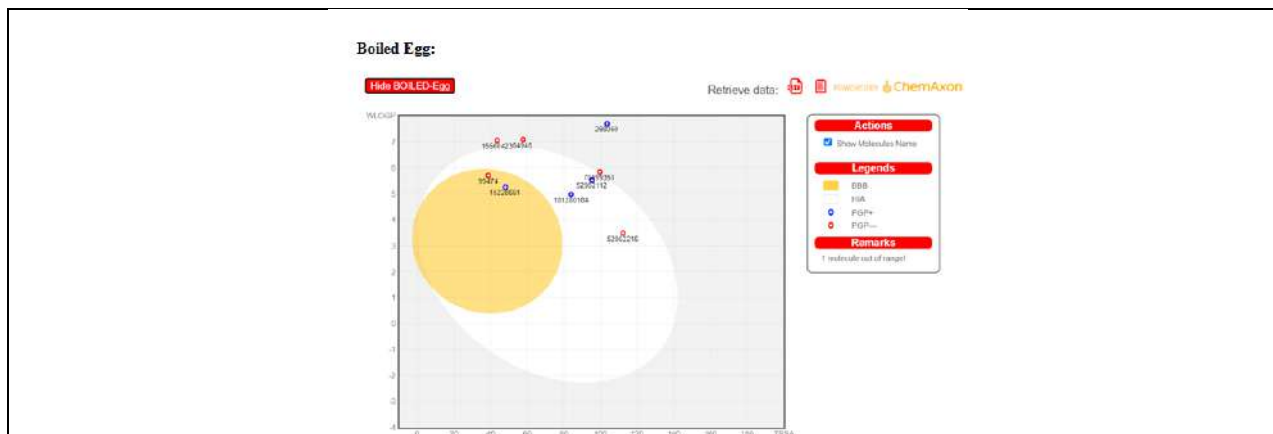


Figure 11: ADMET - Boiled Egg image of best compounds

Note:

BBB: Points located in BOILED-Egg’s yolk are molecules predicted to passively permeate through the blood-brain barrier.

HIA: Points located in BOILED-Egg’s white are molecules predicted to be passively absorbed by the gastrointestinal tract.

PGP+: Blue dots are for molecules predicted to be effluated from the central nervous system by the P-glycoprotein.

PGP-: Red dots are for molecules predicted not to be effluated from the central nervous system by the P-glycoprotein.





Observation and Control of Spin Wave Mode Splitting and Mode Conversion in a Two-Dimensional Diamond Shaped Bicomponent Magnonic Crystal

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ABSTRACT

The static and dynamic magnetization properties of a two-dimensional bicomponent magnonic crystal comprising periodically placed diamond shaped $\text{Ni}_{80}\text{Fe}_{20}$ nanodots embedded in a $\text{Co}_{50}\text{Fe}_{50}$ thin film have been investigated by controlling the strength and azimuthal orientation of the external bias magnetic field. The analysis is based on the outcomes of numerical simulations carried out by the finite difference method based object oriented micromagnetic framework simulator. The obtained spin wave modes show bias magnetic field dependent rich anisotropic spin wave properties, including the presence of spin wave mode splitting and mode conversion. Interestingly, the observed spin wave modes show four-, eight-, and twelve-fold rotational anisotropy with azimuthal orientation of the bias magnetic field due to the combined effects of shape of the nanodot and lattice symmetry. Such bicomponent magnonic crystals offer inter-element exchange coupling combined with long-range anisotropic dipolar interactions, which can open the possibility of developing future magnonic devices.

Keywords: nanomagnetism, magnonic crystal, micromagnetic simulation, magnetization dynamics, spin waves



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INTRODUCTION

Magnonic crystals (MCs) [1,2] are one type of smart artificial materials like photonic crystals [3] and phononic crystals [4]. In magnonics, the propagation of spin waves (SWs) [5] is manipulated by allowing them to propagate through a micro- or nanostructured periodically arranged magnetic elements. On the other hand, spin based technology offer some exciting advantages, for instance, substantially reduced resistive (joule) heating energy loss unlike electronics and SWs with GHz frequencies make MCs a potential candidate to transfer and process of information. The current advancement of nanofabrication techniques facilitates to fabricate the compact integrated circuit. Interestingly, one can tailor the magnonic band structure and SW propagation velocity by patterning a suitable magnetic material into one-, two-, and three-dimensions with different length scales [6–9]. These qualities make MCs suitable for SW-based communication devices e.g. SW filters [10], magnonic waveguides [11], SW-based logic devices [12], phase shifters [13], SW emitters [14], as well as for magnetic data storage [15]. Consequently, extensive research work has been carried out to investigate the magnetization dynamics of ferromagnetic (FM) antidot arrays [16,17], dot arrays [18,19], and nanowires [20]. Here, static and dynamic magnetic properties can be significantly tailored by tuning various internal and external parameters such as material specifications, size [21], shape [22], lattice spacing [23] and also by varying the strength [23,24] and orientation [25] of the external bias magnetic field. Interestingly, the static and dynamic magnetic properties of bicomponent magnonic crystals (BMCs) [26,27] can be controlled more effectively. In a BMC, one FM element is periodically included into a matrix of another FM material; therefore, the difference in their magnetic parameters and inter-element magnetic coupling allow more control over their magnonic bands, which is essential for controlling SWs in MCs for magnon-based computing. Further, the inter-material magnetic coupling is higher at the physical boundaries of two different FM materials due to the exchange interaction. In addition, BMCs show various fascinating properties due to the mode coupling process and high group velocity of the SW through the lateral interface of the bicomponent.

It is therefore crucial to investigate the static and ultrafast dynamic magnetic properties of BMCs to explore their fundamental physics as well as their potential applications. Recent studies of the magnetization dynamics of various types of 1D [28,29], and 2D [30,31] BMCs have been done experimentally by thermal [32] and electrical [33] excitation methods and theoretically by analytical and numerical methods [34,35]. An article [36] reported the application of BMC as an omnidirectional nanograting coupler. Recently, a low-loss magnonic crystal with large tunable band gaps in YIG-CoFeB made BMC have been demonstrated [37]. However, the external bias magnetic strength and azimuthal orientation dependent static and dynamic magnetization properties in BMC, specifically in non-ellipsoidal shaped magnetic nano elements have not been explored extensively. Here, we present a micromagnetic simulation study of external bias magnetic field strength and orientation dependent static and dynamic magnetization properties of a BMC comprising periodically placed diamond shaped $\text{Ni}_{80}\text{Fe}_{20}$ (NiFe) nanomagnets embedded in a $\text{Co}_{50}\text{Fe}_{50}$ (CoFe) thin film. We have obtained rich SW spectra consisting of multiple distinct SW modes in this system that show bias field dependent rich SW properties, including SW mode splitting and mode conversion. Further, an intense anisotropic behaviour of the SW is observed by varying the azimuthal orientation of the bias magnetic field, where SW modes show a clear four-, eight-, and twelve-fold rotational symmetry. Such external bias magnetic field dependent anisotropic SW properties can be useful to develop various spin based devices such as SW directional couplers, splitters, and other reconfigurable devices.

MATERIALS AND METHODS

The micromagnetic simulations have been carried out using the OOMMF (Object Oriented Micromagnetic Framework) [38] simulator. We have studied two-dimensional array of 20 nm thick diamond shaped NiFe elements, which have been considered in a square lattice arrangement embedded in a CoFe thin film of same thickness. Each diamond dot is 300 nm in length and width, and the closest edge-to-edge separation is 60 nm. The array were made of 7×7 elements to include the effect of long-range magnetostatic interaction in a large array. The bicomponent





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sample was discretized into rectangular prism-like cells of $4 \times 4 \times 20 \text{ nm}^3$ dimensions. The lateral dimensions of the cells were taken below the exchange length, $l_{\text{ex}} = \sqrt{\frac{2A}{\mu_0 M^2}}$ of both NiFe and CoFe to take account of the short-range exchange interaction. The saturation magnetization (M) and exchange stiffness (A) parameters used during the simulation [31] are $M_{\text{NiFe}} = 800 \text{ emu/cc}$, $A_{\text{NiFe}} = 1.3 \times 10^{-6} \text{ erg/cm}$, for NiFe, and $M_{\text{CoFe}} = 1800 \text{ emu/cc}$, $A_{\text{CoFe}} = 3 \times 10^{-6} \text{ erg/cm}$ for CoFe. The gyromagnetic ratio, $\gamma = 18.5 \text{ MHz/Oe}$ and the magneto crystalline anisotropy, $K = 0$ have been considered for both materials. The exchange stiffness constant, $A_{\text{Exch}} = 2.1 \times 10^{-6} \text{ erg/cm}$ is considered at the NiFe/CoFe interface to ensure strong inter-material interaction between CoFe and NiFe [39,40]. The whole simulation process is composed of two primary parts: (i) static and (ii) dynamic. After completion of the static part, the final magnetization state, i.e., 'the static magnetic configuration' is obtained and it is specified as the initial magnetization state for the dynamic part. The static magnetic configuration was obtained by first applying a large enough bias magnetic field (2.0 Tesla) to fully magnetize the sample and allowing the magnetization to relax for 1 ns. The applied bias field was then reduced to the bias field values and the magnetization was further allowed to relax for another 1 ns. During this process the damping coefficient (α) was set at 0.95 so that the precession dies down quickly and the magnetization fully relaxes within 1 ns. Subsequently, a pulse magnetic field $h(t)$, with peak amplitude of 30 Oe as an excitation field, was applied to the sample to compute the dynamic magnetization averaged over the entire sample volume for a total duration of 4 ns at intervals of 10 ps. During dynamic simulations, the damping coefficient (α) of 0.01 was utilised to ensure that the precession fades quickly. Consequently, the simulated line widths of the resonant modes are narrow enough, which enabled us to clearly resolve the SW mode splitting in the simulation. The micromagnetic simulations are described in details elsewhere[41].

RESULTS AND DISCUSSION

The external bias magnetic field strength (H) and azimuthal orientation (ϕ) dependent static and dynamic magnetization properties of diamond shaped BMC has been investigated. shape (Navy blue colour) embedded in a $\text{Co}_{50}\text{Fe}_{50}$ thin film (Red colour). The inset shows the azimuthal orientation (ϕ) of the external bias magnetic field (H). (b) Background subtracted time-resolved precessional magnetization (M_z) traces obtained at $H = 1.0 \text{ kOe}$ for $\phi = 0^\circ$. (c) Corresponding FFT power spectra of time-domain precession obtained at $H = 1.0 \text{ kOe}$ for $\phi = 0^\circ$. Arrow signs represent different SW modes. Figure 1(a) shows a schematic of the simulation geometry. The external bias magnetic field orientation is shown in Fig.1(a). The exemplary bi-exponential background-subtracted time-resolved magnetization precessional data for the BMC is shown in Fig. 1(b) at $\phi = 0^\circ$ for $H = 1.0 \text{ kOe}$. It shows a damped non-uniform oscillation, which confirms the presence of multiple precessional modes in the system. A fast Fourier transform (FFT) is performed over this time-resolved precessional data to obtain the power versus frequency spectrum as presented in Fig. 1(c), which clearly indicates the presence of five distinct SW modes in the sample at $\phi = 0^\circ$ for $H = 1.0 \text{ kOe}$. The obtained SW modes are marked with arrow signs.

Notably, permalloy is a soft ferromagnetic material possessing very negligible magneto crystalline anisotropy, which makes it an ideal material for nanopatterning into complex geometrical configurations. Permalloy also makes it easy to examine the impact of the shape anisotropy of the nano-patterned ferromagnetic elements and their interactions with one another when arranged in a 2D array. Figure 2 represents the variation of the precessional frequency of the SW modes present in the system with H . The time-resolved magnetization (M_z) traces and corresponding FFT power spectra for the BMC at different values of H obtained at $\phi = 0^\circ$ are presented in Figs. 2(a-f). It reveals that the precessional frequency of the SW modes increases systematically with the increment of H . Interestingly, a splitting of mode 2 is observed at $H \approx 1.2 \text{ kOe}$ with the appearance of mode 1. The frequency gap between these two modes (mode 1 and mode 2) increases with each increment of H . Notably, second SW mode splitting is observed for mode 5 at $H \approx 1.1 \text{ kOe}$ with the appearance of mode 5*. In addition, power transfer from mode 5* to mode 5 is detected with each successive increment of H . Figure 3(a) shows quantitatively the frequency gap between mode 1 and mode 2 as a function of H . It shows the frequency gap increases almost linearly with the increment of H in this regime. On the other hand, the peak power values of modes 5 and 5* as a function of H are shown in Fig. 3(b). A clear power transfer





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from mode 5* to mode 5 is detected as a function of H . Therefore, a SW mode conversion between mode 5 and mode 5* is revealed in the diamond shaped BMC with the variation of H . The SW modes show drastic changes with ϕ . Figure 4(a) shows five distinct SW modes, with the maximum peak power of mode 5 at $\phi=0^\circ$. Interestingly, mode 5* becomes the main SW mode with maximum peak power of the system as ϕ is rotated by 15° only as shown in Fig. 4(b). Subsequently, a new higher frequency SW mode (mode 6) is observed at $\phi=30^\circ$ as shown in Fig. 4(c). Therefore, the total number of SW modes increases from five to six with each increment of ϕ . Notably, a drastic decrease in the number of SW modes is observed at $\phi=45^\circ$. The number of SW modes becomes three at $\phi=45^\circ$ with the maximum peak power of mode 4 as shown in Fig. 4(d). Again, the number of SW modes increases to six at $\phi=60^\circ$ with the maximum peak power of mode 5* as shown in Fig. 4(e). With further increments of ϕ , five distinct SW modes at $\phi=75^\circ$ have been observed as shown in Fig. 4(f). Finally, Fig. 4(g) shows five SW modes with the maximum power of mode 5 at $\phi=90^\circ$ similar to at $\phi=0^\circ$. Basically, due to the configurational symmetry of the system, the magnetization dynamics behave alike at some specific orientations of H like $\phi=0^\circ$, 15° , and 30° , with $\phi=90^\circ$, 75° , and 60° , respectively. Figure 5(a) represents the variation of the precessional frequencies of the SW modes as a function of H applied at $\phi=0^\circ$. The plot reveals rich anisotropic SW properties.

The precessional frequencies of the SW modes vary non-monotonically as a function of H . The highest frequency mode (mode 5) shows a mode splitting (appearance of mode 5*) for $H \lesssim 1.1$ kOe. On the other hand, mode 2 shows another mode splitting for $H \gtrsim 1.2$ kOe. On the contrary, the intermediate frequency branches (mode 3 and mode 4) show a continuous decrease in precessional frequency with the decrease of H . Figure 5(b) represents modulation of the precessional frequencies of the SW modes with ϕ at $H=1.0$ kOe. A significant modulation of precessional frequencies is observed with the variation of ϕ . The sinusoidal fits clearly manifest that both mode 3 and mode 4 show an anisotropic nature with an eight-fold rotational symmetry, although their anisotropic natures are in opposite phases with each other. Notably, mode 2 shows highly anisotropic behaviour with a twelve-fold rotational symmetry. While, mode 5* shows an anisotropic nature with four-fold rotational symmetry. The tetragonal shape of the NiFe element and square-shaped lattice arrangement of the NiFe elements on the CoFe matrix are jointly responsible for the occurrence of four-, eight-, and twelve-fold symmetries in the SW modes. However, mode 5 does not show any sinusoidal anisotropy. Therefore, it is not presented here. For a deep understanding of the origin of the SW modes in ferromagnetic diamond shaped BMC, the bias field dependent spin wave spectra for a single diamond shaped NiFe element embedded in CoFe thin film at $\phi=0^\circ$ are further simulated as shown in Fig. 6. Two distinct SW modes are observed for the H values of 0.5 kOe, 0.8 kOe, and 1.1 kOe as shown by Figs. 6(a), 6(b) and 6(c), respectively. Interestingly, a new SW mode is detected along with the previous two modes at $H=1.4$ kOe as shown in Fig. 6(d). However, the diamond shaped BMC shows a minimum of five SW modes for $\phi=0^\circ$. Therefore, the presence of additional SW modes in the BMC indicates the existence of strong anisotropic dipolar interactions between the diamond dots in the array, which are most likely responsible for the splitting of mode 5 for $H \lesssim 1.1$ kOe.

In the case of dipolar field coupled diamond dots in the horizontal direction (x axis), the dipolar field is added to the applied external magnetic field. On the contrary, with dipolar field coupled diamond dots in the vertical direction (y axis), the effective field is reduced due to this anisotropic dipolar field. Probably, these two contrasting dipolar fields along horizontal and vertical axes are the origin of SW mode splitting between mode 1 and mode 2. Now with the increase of H , the difference of the effective dipolar field along the x and y axes increases, this may be responsible for the increment of the frequency gap between mode 1 and mode 2 with the increase of H . In addition, for a profound understanding of the magnetization dynamics, the static magnetic configuration for the BMC at different H and ϕ values is simulated as shown in Figs. 7(a–c) and Figs. 8(a–c), respectively. The bending of the spins is more at the lower H values, specifically between the diamond dots in the horizontal direction as shown in Fig. 7(a). The spins become straight along the bias field direction with the increment of H as depicted in Figs. 7(b–c). Therefore, the nature of intra-element and inter-element magnetic field distributions in the diamond shaped BMC can be tuned with the variation of the strength of H , which in turn modifies its SW dynamics. Probably this modified SW dynamics is responsible for the origin of mode conversion between mode 5 and mode 5*. On the other hand, as the azimuthal orientation of H changes from $\phi=0^\circ$ to $\phi=15^\circ$, spins are deflected from the x axis to the y axis as shown in Fig. 8(a). Whereas at $\phi=30^\circ$, the modified demagnetization field makes the internal field distribution such that the diamond



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dots tend to look connected in the horizontal direction as represented in Fig. 8(b). Interestingly, at $\phi = 45^\circ$ the diamond dots become effectively connected in the horizontal direction as depicted in Fig. 8(c), and the spins significantly align along the y axis, which is likely to be responsible for the occurrence of the minimum number of SW modes at $\phi = 45^\circ$. In addition, as the diamond shaped BMC are planar 2D arrays, they can be easily integrated with on-chip devices. Our study is therefore important for the development of nanoscale spintronic and magnonic devices.

CONCLUSIONS

In summary, the static and dynamic magnetization properties of diamond shaped BMC has been investigated by controlling the strength and azimuthal orientation of the external bias magnetic field using micromagnetic simulations. The precessional magnetization dynamics of the BMC show rich SW spectra with the presence of a maximum of six SW modes. The bias field dependent SW spectra reveal the existence of two SW mode splitting in the BMC. In the case of lower frequency mode splitting, the frequency gap between mode 1 and mode 2 increases with the increment of bias field strength due to the effect of two contrasting anisotropic dipolar fields. Whereas for higher frequency mode splitting, peak power values of the SW modes reveal a power transfer from mode 5* to mode 5 with the successive increment of bias field strength due to the mode conversion between these two modes. The SW modes show rich anisotropic properties with the change in azimuthal orientation of the bias field. The number of SW modes and their peak power values show drastic variation with ϕ . Interestingly, due to the symmetrical configurational anisotropy of the diamond shaped BMC, the magnetization dynamics act similarly at specific orientations of H like $\phi = 0^\circ, 15^\circ, \text{ and } 30^\circ$ with $\phi = 90^\circ, 75^\circ, \text{ and } 60^\circ$, respectively. Mode 3 and mode 4 possess eight-fold anisotropy, having opposite phases to each other. However, mode 2 shows strong anisotropic behaviour with twelve-fold symmetry, while mode 5* has weak anisotropic behaviour with four-fold rotational symmetry. The tetragonal shape of the NiFe element and square-shaped lattice arrangement of the NiFe elements on the CoFe matrix are jointly responsible for the occurrence of four-, eight-, and twelve-fold rotational symmetries in the SW modes. Also, the bias field dependent power spectra for a single diamond element reveal the presence of strong anisotropic dipolar interactions between the diamond dots in the array. In addition, the static magnetic configuration for the BMC at different bias field values exhibits the origin of mode conversion between mode 5 and mode 5* as a bias field driven modification of SW dynamics. On the contrary, the static magnetic configurations of the BMC obtained by varying the azimuthal orientation of the bias field disclose how the modified internal field distribution makes diamond dots effectively connected in the horizontal direction, which is likely to be responsible for the occurrence of the minimum number of SW modes at $\phi = 45^\circ$. Such an ability to tune the static magnetic configuration and ultrafast magnetization dynamics in diamond shaped BMC by the external bias field strength and azimuthal orientation opens a new possibility of developing magnonic as well as spintronic devices.

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REFERENCES

1. S. Neusser, and D. Grundler, *Adv. Mater.* **21**,2927 (2009). <https://doi.org/10.1002/adma.200900809>
2. S. A. Nikitov, Ph. Tailhades, and C. S. Tsai, *J. Magn. & Magn. Mater.* **236**,320 (2001). [https://doi.org/10.1016/S0304-8853\(01\)00470-X](https://doi.org/10.1016/S0304-8853(01)00470-X)



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3. X. Lv, B. Zhong, Y. Huang, Z. Xing, H. Wang, et al., Chin. J. Mech. Eng. **36**, 1 (2023).<https://doi.org/10.1186/s10033-023-00836-2>
4. M. I. Hussein, M. J. Leamy, and M. Ruzzene, Appl. Mech. Rev. **66**,040802 (2014).<https://doi.org/10.1115/1.4026911>
5. A. Mahmoud, F. Ciubotaru, F. Vanderveken, A. V. Chumak, S. Hamdioui, C. Adelman, and S. Cotofana, J. Appl. Phys. **128**,161101 (2020).<https://doi.org/10.1063/5.0019328>
6. C. Banerjee, S. Choudhury, J. Sinha, and A. Barman, Phys. Rev. Appl. **8**,014036 (2017).<https://doi.org/10.1103/PhysRevApplied.8.014036>
7. S.Saha, R. Mandal, S. Barman, D. Kumar, B. Rana, Y. Fukuma, S. Sugimoto, Y. Otani, and A. Barman, Adv. Funct. Mater. **23**,2378 (2013). <https://doi.org/10.1002/adfm.201202545>
8. S.Tacchi, F. Montoncello, M. Madami, G. Gubbiotti, G. Carlotti, L. Giovannini, R. Zivieri, F. Nizzoli, S. Jain, A. O. Adeyeye, and N. Singh, Phys. Rev. Lett. **107**,127204 (2011).<https://doi.org/10.1103/PhysRevLett.107.127204>
9. A. Fernández-Pacheco, R. Streubel, O. Fruchart, R. Hertel, P. Fischer, and R. P. Cowburn, Nat. Commun. **8**,15756 (2017).<https://doi.org/10.1038/ncomms15756>
10. S. -K. Kim, K. -S. Lee, and D. -S. Han, Appl. Phys. Lett. **95**,082507 (2009).<https://doi.org/10.1063/1.3186782>
11. A. Haldar, and A. O. Adeyeye, Appl. Phys. Lett. **119**,060501 (2021).<https://doi.org/10.1063/5.0061528>
12. J. Ding, M. Kostylev, and A. O. Adeyeye, Appl. Phys. Lett. **100**,073114 (2012).<https://doi.org/10.1063/1.3687177>
13. Y. Au, M. Dvornik, O. Dmytriiev, and V. V. Kruglyak, Appl. Phys. Lett. **100**,172408 (2012).<https://doi.org/10.1063/1.4705289>
14. S. Kaka, M. R. Puffall, W. H. Rippard, T. J. Silva, S. E. Russek, and J. A. Katine, Nature **437**,389 (2005).<https://doi.org/10.1038/nature04035>
15. B. D. Terris, and T. Thomas, J. Phys. D: Appl. Phys. **38**,199 (2005).<https://doi.org/10.1088/0022-3727/38/12/R01>
16. S. Neusser, G. Duerr, H. G. Bauer, S. Tacchi, M. Madami, G. Woltersdorf, G. Gubbiotti, C. H. Back, and D. Grundler, Phys. Rev. Lett. **105**,067208 (2010).<https://doi.org/10.1103/PhysRevLett.105.067208>
17. S. Tacchi, B. Botters, M. Madami, J. W. Klos, M. L. Sokolovskyy, M. Krawczyk, G. Gubbiotti, G. Carlotti, A. O. Adeyeye, S. Neusser, and D. Grundler, Phys. Rev. **B86**,014417 (2012).<https://doi.org/10.1103/PhysRevB.86.014417>
18. R. P. Cowburn, J. Magn. Magn. Mater. **242**, 505 (2002).[https://doi.org/10.1016/S0304-8853\(01\)01086-1](https://doi.org/10.1016/S0304-8853(01)01086-1)
19. G. Gubbiotti, G. Carlotti, T. Okuno, T. Shinjo, F. Nizzoli, and R. Zivieri, Phys. Rev. **B68**,184409 (2003).<https://doi.org/10.1103/PhysRevB.68.184409>
20. J. Topp, G. Duerr, K. Thurner, and D. Grundler, Pure Appl. Chem. **83**, 1989 (2011).<https://doi.org/10.1351/PAC-CON-11-03-06>
21. V. V. Kruglyak, A. Barman, R. J. Hicken, J. R. Childress, and J. A. Katine, J. Appl. Phys. **97**, 10A706 (2005).<https://doi.org/10.1063/1.1849057>
22. R. Mandal, P. Laha, K. Das, S. Saha, S. Barman, A. K. Raychaudhuri, and A. Barman, Appl. Phys. Lett. **103**, 262410 (2013).<https://doi.org/10.1063/1.4860959>
23. K. Adhikari, S. Choudhury, R. Mandal, S. Barman, Y. Otani, and A. Barman, J. Appl. Phys. **121**,043909 (2017).<https://doi.org/10.1063/1.4974886>
24. S. Pal, S. Saha, M. V. Kamalakar, and A. Barman, Nano Research **9**,1426 (2016).<https://doi.org/10.1007/s12274-016-1038-5>
25. K. Adhikari, S. Barman, R. Mandal, Y. Otani, and A. Barman, Phys. Rev. Appl. **10**,044010 (2018).<https://doi.org/10.1103/PhysRevApplied.10.044010>
26. J. O. Vasseur, L. Dobrzynski, B. Djafari-Rouhani, and H. Puzkarski, Phys. Rev. **B54**, 1043 (1996).<https://doi.org/10.1103/PhysRevB.54.1043>
27. S. Tacchi, G. Duerr, J. W. Klos, M. Madami, S. Neusser, et al., Phys. Rev. Lett. **109**, 137202 (2012).<https://doi.org/10.1103/PhysRevLett.109.137202>
28. Z. K. Wang, V. L. Zhang, H. S. Lim, S. C. Ng, M. H. Kuok, et al., ACS Nano **4**, 643 (2010).<https://doi.org/10.1021/nn901171u>
29. J. Rychly, and J. W. Klos, J. Phys. D: Appl. Phys. **50**,164004 (2017).<https://doi.org/10.1088/1361-6463/aa5ae1>
30. A. O. Adeyeye, S. Jain, and Y. Ren, IEEE Trans. Magn. **47**,1639 (2011).<https://doi.org/10.1109/TMAG.2010.2103554>





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31. S. Choudhury, S. Saha, R. Mandal, S. Barman, Y. Otani, and A. Barman, ACS Appl. Mater. Interfaces8, 19339 (2016).<https://doi.org/10.1021/acsami.6b04011>
32. G. Duerr, S. Tacchi, G. Gubbiotti, and D. Grundler, J. Phys. D: Appl. Phys. 47, 325001 (2014).<https://doi.org/10.1088/0022-3727/47/32/325001>
33. X. M. Liu, J. Ding, and A. O. Adeyeye, Appl. Phys. Lett. 100,242411 (2012).<https://doi.org/10.1063/1.4729428>
34. M. Krawczyk, S. Mamica, M. Mruczkiewicz, et al., J. Phys. D: Appl. Phys. 46,495003 (2013).<https://doi.org/10.1088/0022-3727/46/49/495003>
35. F. S. Ma, H. S. Lim, Z. K. Wang, et al., Appl. Phys. Lett.98, 153107 (2011).<https://doi.org/10.1063/1.3579531>
36. H. Yu, G. Duerr, R. Huber, B. Bahr, T. Schwarze, et al., Nat. Commun. 4,2702 (2013).<https://doi.org/10.1038/ncomms3702>
37. H. Qin, G. -J. Both, S. J. Hämaläinen, L. Yao, and S. V. Dijken, Nat. Commun. 9, 5445 (2018).<https://doi.org/10.1038/s41467-018-07893-5>
38. M. Donahue, and D. G. Porter, OOMMF User’s Guide, Version 1.0, NIST Interagency Report No. 6376, National Institute of Standards and Technology, Gaithersburg, MD, 1999.<https://doi.org/10.6028/NIST.IR.6376>
39. P. Malago, L. Giovannini, R. Zivieri, P. Gruszecki, and M. Krawczyk, Phys. Rev. B92, 064416 (2015).<https://doi.org/10.1103/PhysRevB.92.064416>
40. V. L. Zhang, H. S. Lim, C. S. Lin, Z. K. Wang, S. C. Ng, et al., Appl. Phys. Lett. 99,143118 (2011).<https://doi.org/10.1063/1.3647952>
41. A. Barman, and S. Barman, Phys. Rev. B79,144415(2009).<https://doi.org/10.1103/PhysRevB.79.144415>

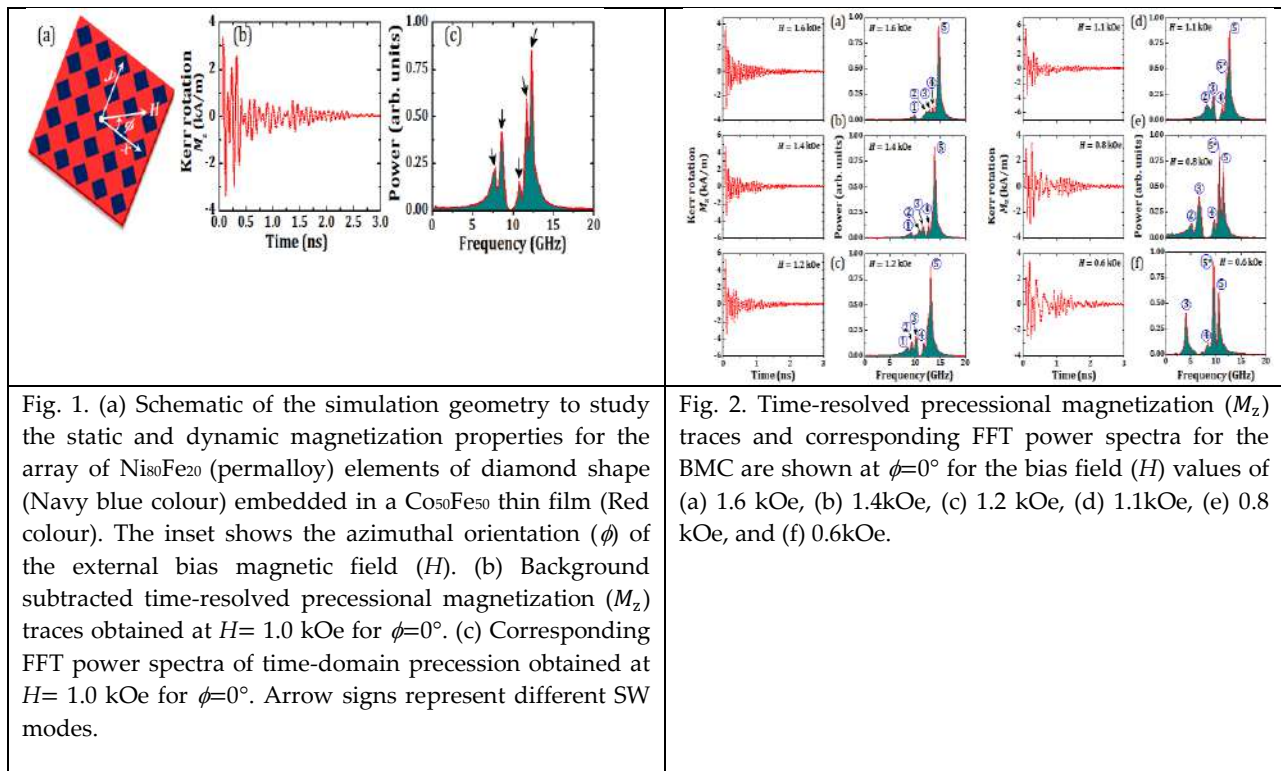


Fig. 1. (a) Schematic of the simulation geometry to study the static and dynamic magnetization properties for the array of $\text{Ni}_{80}\text{Fe}_{20}$ (permalloy) elements of diamond shape (Navy blue colour) embedded in a $\text{Co}_{50}\text{Fe}_{50}$ thin film (Red colour). The inset shows the azimuthal orientation (ϕ) of the external bias magnetic field (H). (b) Background subtracted time-resolved precessional magnetization (M_z) traces obtained at $H = 1.0$ kOe for $\phi = 0^\circ$. (c) Corresponding FFT power spectra of time-domain precession obtained at $H = 1.0$ kOe for $\phi = 0^\circ$. Arrow signs represent different SW modes.

Fig. 2. Time-resolved precessional magnetization (M_z) traces and corresponding FFT power spectra for the BMC are shown at $\phi = 0^\circ$ for the bias field (H) values of (a) 1.6 kOe, (b) 1.4 kOe, (c) 1.2 kOe, (d) 1.1 kOe, (e) 0.8 kOe, and (f) 0.6 kOe.





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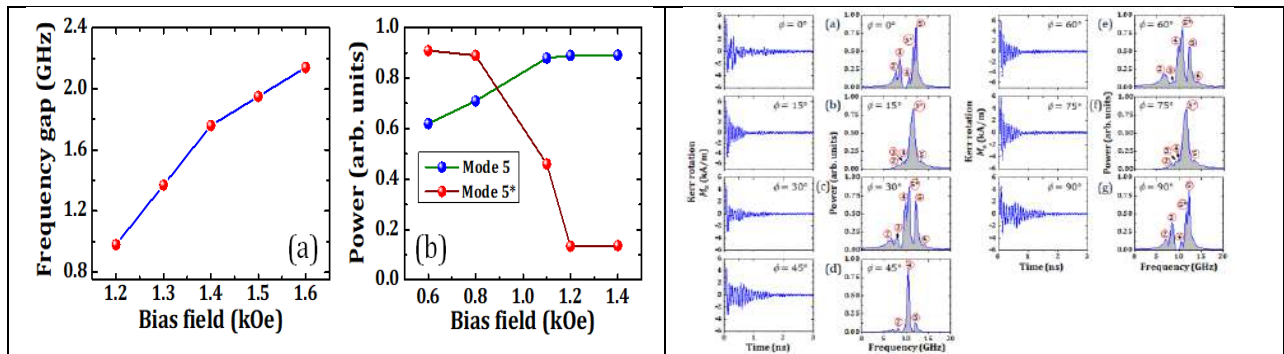


Fig. 3. (a) The frequency gap between mode 1 and mode 2 is shown as a function of H . (b) The peak power values of modes 5* and 5 are shown as a function of H . The inset shows the colour code for those two SW modes.

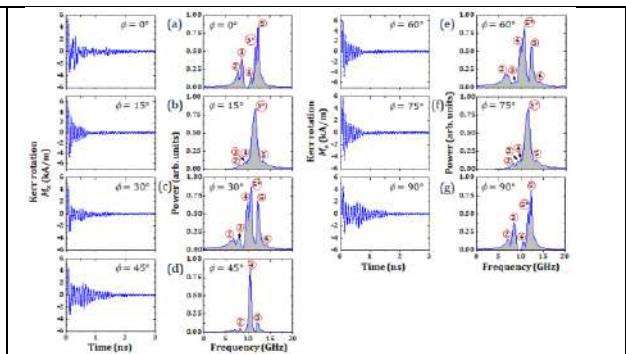


Fig. 4. Time-resolved precessional magnetization (M_z) traces and corresponding FFT power spectra for the BMC are shown at $H=1.0$ kOe and for the bias field orientations (ϕ) of (a) 0° , (b) 15° , (c) 30° , (d) 45° , (e) 60° , (f) 75° , and (g) 90° .

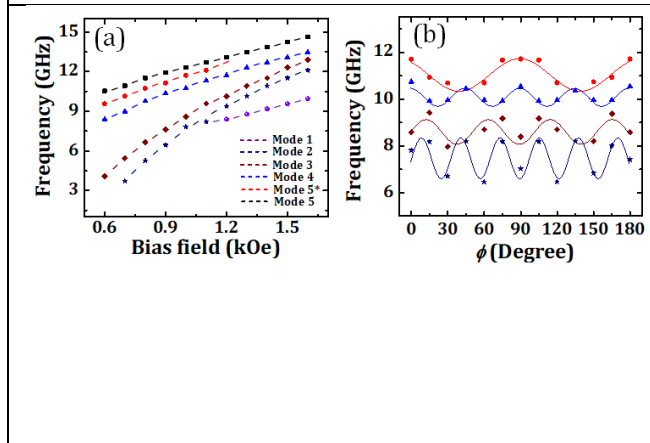


Fig. 5. (a) Variation of the precessional frequencies of the SW modes as a function of H applied at $\phi=0^\circ$. The dotted line is a guide for the eye. (b) Modulation of the precessional frequencies of the SW modes (mode 2, mode 3, mode 4, and mode 5*) as a function of ϕ for $H=1.0$ kOe. The continuous lines represent sinusoidal fits for the SW modes obtained from the BMC.

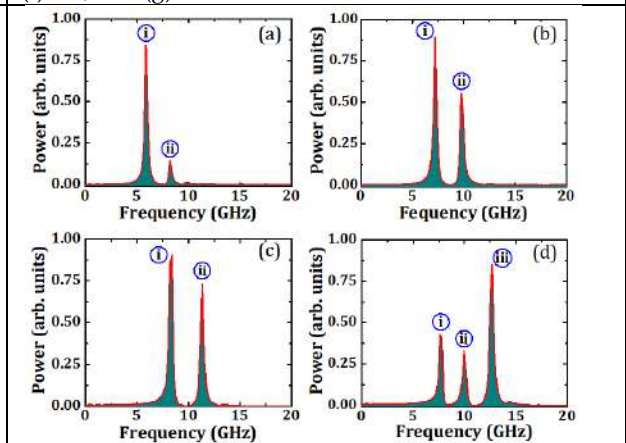


Fig. 6. FFT power spectra for the single $Ni_{80}Fe_{20}$ element of diamond shape embedded in $Co_{50}Fe_{50}$ thin film are shown at $\phi=0^\circ$ for the bias field (H) values of (a) 0.5 kOe, (b) 0.8 kOe, (c) 1.1 kOe, and (d) 1.4 kOe.

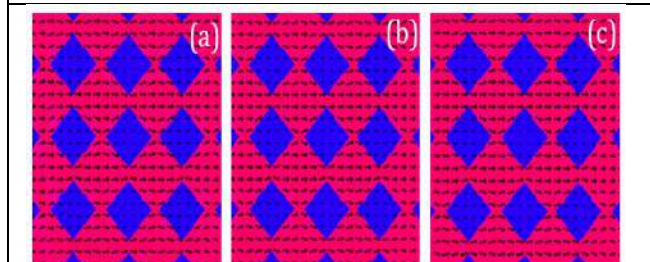


Fig. 7. Static magnetic configurations for BMC are shown at $\phi=0^\circ$ for the bias field (H) values of (a) 0.5 kOe, (b) 1.1 kOe, and (c) 1.4 kOe.

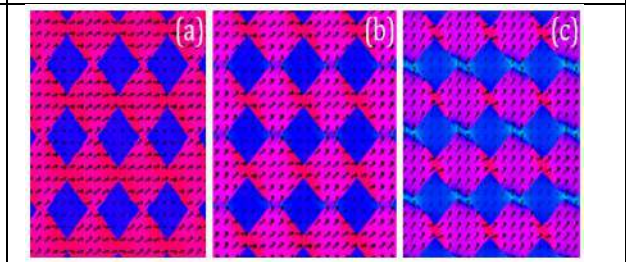


Fig. 8. Static magnetic configurations for BMC are shown at $H=1.0$ kOe for the bias field orientations (ϕ) of (a) 15° , (b) 30° , and (c) 45° .





Some Continuous Maps in Soft Topological Spaces

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ABSTRACT

This research study focuses on the development and analysis of a new type of continuous mapping called the Soft J^c continuous map. The study aims to determine the uniqueness and effectiveness of the Soft J^c continuous map by comparing it to existing types of soft continuous maps. In addition, the study provides a comprehensive understanding of the functionality of the Soft J^c continuous map by analysing its properties in detail. The study also introduces the Soft J^c irresolute map and compares it to other types of irresolute mapping, including the Soft J^c continuous map. Additionally, the study introduces the Soft T_{J^c} space. The Soft J^c irresolute map is analysed in-depth to determine its strengths, limitations, and potential applications in various fields. this research study provides valuable insights into the development and analysis of continuous mappings, particularly the Soft J^c continuous map and the Soft J^c irresolute map.

Keywords: Soft mapping, Softcontinuous, Soft J^c continuous map, Soft J^c irresolute map, Soft Topology.

INTRODUCTION

Soft sets were initially proposed in 1999 by Molodtsov D [3] as a means of confronting uncertainty in a more flexible and parametric way. Soft sets represent a generalization of the conventional set theory whereby, instead of employing rigid boundaries, they offer a more adaptive approach to modelling uncertainty. In 2002, P. K. Maji et al.[7] presented some important terms for soft set theory. These definitions allowed for a more systematic and rigorous approach to soft set theory. Muhammad Shabir and Naz[6] further expanded soft set theory by introducing





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Soft topological spaces. Soft topological spaces allow for the study of soft sets in the context of topology and provide a framework for further development of soft set theory. In 2013, Aras and Sonmez[2] presented soft continuous mapping and its characteristics. Soft continuous mappings are a generalization of traditional continuous mappings, where instead of exact mappings, Soft continuous mappings allow for a more flexible approach to continuity. Soft nearly g -continuous functions were first proposed and discussed by A. Selvi and I. Arockiarani[1] in 2015. Soft nearly g -continuous functions are a generalization of almost g -continuous functions and provide a framework for studying continuity in soft set theory. In 2017, Pious Missier, and Jackson[10] introduced soft JP continuous functions. In a previous study, Soft J^c closed set, and the Soft J^c open set were introduced. These concepts provide a framework for studying Soft sets in the context of soft J^c open sets, which are a generalization of open sets. This research study presents a novel type of continuous mapping, the Soft J^c continuous map, which has been thoroughly developed and analyzed. The Soft J^c continuous map has been compared to existing types of soft continuous maps, demonstrating its unique and effective qualities. In addition, the properties of the Soft J^c continuous map have been extensively investigated, providing a comprehensive understanding of its functionality. Moreover, the study introduces the Soft J^c irresolute map, which has been analysed in detail to determine its potential applications in various fields by identifying its strengths and limitations. The Soft J^c irresolute map has been compared to the Soft J^c continuous map and other types of irresolute mapping, further highlighting its significance.

PRELIMINARIES

Definition 2.1[3] A **S-set** M_A on the universe G is defined by the set of ordered pairs $M_A = \{(g, m_a(g)) : g \in E \text{ and } m_a(x) \in P(G)\}$, where $m_a: A \rightarrow P(G)$ such that $m_a(g) = \phi$ for all $g \notin A$. Hence m_a is called an approximate function of the S-set M_A . The value of m_a may be arbitrary, some of them may be empty, some may have non empty intersection.

Definition 2.2[7]

1. A S-set (M_A) over G is said to be **Null S-set** denoted by M_ϕ or $\tilde{\phi}$ if for all $e \in A$, $M(e) = \tilde{\phi}$.
2. A S-set (M_A) over G is said to be an **Absolute S-set** denoted by M_G or \tilde{G} if for all $e \in A$, $M(e) = G$.

Definition 2.3[6] Consider τ be a collection of S-sets over G with a fixed set E of parameters. Then, τ is called a **STon** G if

1. $\tilde{\phi}, \tilde{G} \in \tau$.
2. The union of any number of S-sets in τ belongs to τ .
3. The intersection of any two S-sets in τ belongs to τ .

The triplet (G, τ_E) is called **ST space** over G . The members of τ are called **S-open** sets in G and complements of them are called **S-closed** sets in G .

Definition 2.4[8] A **S- J^c closed set** is s-subset(Y_E) of as ST space (G, τ_E) if $Scl^*(Y_E) \subseteq (U_E)$ when-ever $(Y_E) \subseteq (U_E)$ and (U_E) is s-semi*open set. $SJ^cC(G)$ represents the collection of all S- J^c closed sets.

Definition 2.5[8] A **S- J^c open set** is a s-subset(Y_E) of a ST space (G, τ_E) if it's complement is S- J^c closed set and noted by $SJ^cO(G)$.

Definition 2.6[2,4,5,10] A s-map $m: (G, \tau_E) \rightarrow (H, \sigma_K)$ is said to be

1. **S-continuous** if $m^{-1}(B_K)$ is s-open set in (G, τ_E) for each one of the s-open set (B_K) in (H, σ_K) .
2. **S-semi-continuous** if $m^{-1}(B_K)$ is s-semi-open set in (G, τ_E) for each one of the s-open set (B_K) in (H, σ_K) .
3. **S-g-continuous** if $m^{-1}(B_K)$ is s-g-open set in (G, τ_E) for each one of the s-open set (B_K) in (H, σ_K) .
4. **S- \hat{g} -continuous** if $m^{-1}(B_K)$ is s- \hat{g} -open set in (G, τ_E) for each one of the s-open set (B_K) in (H, σ_K) .
5. **S-JP-continuous** if $m^{-1}(B_K)$ is s-JP-open set in (G, τ_E) for each one of the s-open set (B_K) in (H, σ_K) .
6. **S-J-continuous** if $m^{-1}(B_K)$ is s-J-open set in (G, τ_E) for each one of the s-open set (B_K) in (H, σ_K) .





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7. **S-J_c-continuous** if $m^{-1}(B_K)$ is $s\text{-}J_c$ -open set in (G, τ_E) for each one of the s -open set (B_K) in (H, σ_K) .

Definition 2.7[2,5,10] A s -map $m: (G, \tau_E) \rightarrow (H, \sigma_K)$ is said to be

1. **S-irresolute** if $m^{-1}(D_K)$ is s -semi-open set in (G, τ_E) for each one of the s -semi-open set (D_K) in (H, σ_K) .
2. **S- \hat{g} -irresolute** if $m^{-1}(D_K)$ is $s\text{-}\hat{g}$ -open set in (G, τ_E) for each one of the $s\text{-}\hat{g}$ -open set (D_K) in (H, σ_K) .
3. **S-JP-irresolute** if $m^{-1}(D_K)$ is $s\text{-}JP$ -open set in (G, τ_E) for each one of the $s\text{-}JP$ -open set (D_K) in (H, σ_K) .
4. **S-J-irresolute** if $m^{-1}(D_K)$ is $s\text{-}J$ -open set in (G, τ_E) for each one of the $s\text{-}J$ -open set (D_K) in (H, σ_K) .
5. **S-J_c-irresolute** if $m^{-1}(D_K)$ is $s\text{-}J_c$ -open set in (G, τ_E) for each one of the $s\text{-}J_c$ -open set (D_K) in (H, σ_K) .

S-J^c CONTINUOUS MAP

Definition 3.1: A s -map $m: (G, \tau_E) \rightarrow (H, \sigma_K)$ is said to be **S-J^c continuous map** if $m^{-1}(A_K)$ is $S\text{-}J^c$ closed set in (G, τ_E) for every s -closed set (A_K) in (H, σ_K) .

Theorem 3.2: A s -map $m: (G, \tau_E) \rightarrow (H, \sigma_K)$ is $S\text{-}J^c$ continuous if $m^{-1}(P_K)$ is $S\text{-}J^c$ open set in (G, τ_E) for each s -open set (P_K) in (H, σ_K) .

Proof: Consider $m: (G, \tau_E) \rightarrow (H, \sigma_K)$ be a $S\text{-}J^c$ continuous and (P_K) be s -open set in (H, σ_K) . We get, $(P_K)^c$ is s -closed set in $(H, \sigma_K) \Rightarrow m^{-1}(P_K)^c$ is $S\text{-}J^c$ closed set in (G, τ_E) . Hence, $m^{-1}(P_K)$ is $S\text{-}J^c$ open set in (G, τ_E) .

Theorem 3.3: Let $m: (G, \tau_E) \rightarrow (H, \sigma_K)$ be a s -map. If

1. m is s -continuous then it is $S\text{-}J^c$ continuous. But $S\text{-}J^c$ continuous is not s -continuous.
2. m is s -semi-continuous. Then m is $S\text{-}J^c$ continuous and $S\text{-}J^c$ continuous is not s -semi-continuous.
3. m is $S\text{-}\alpha$ -continuous. Then it is $S\text{-}J^c$ continuous and $S\text{-}J^c$ continuous is not $S\text{-}\alpha$ -continuous.

Proof

1. Consider $m: (G, \tau_E) \rightarrow (H, \sigma_K)$ is s -continuous and $m^{-1}(Q_K)$ is s -closed set in (G, τ_E) for each s -closed set in (H, σ_K) . Since s -closed sets are all $S\text{-}J^c$ closed set. Then $m^{-1}(Q_K)$ is $S\text{-}J^c$ closed set in (G, τ_E) for each s -closed set in (H, σ_K) . Hence, m is $S\text{-}J^c$ continuous.
2. Consider the mapping $m: (G, \tau_E) \rightarrow (H, \sigma_K)$ is s -semi-continuous. Since all s -semi-closed set are $S\text{-}J^c$ closed set. Then for each s -closed set (S_K) in (H, σ_K) , $m^{-1}(S_K)$ is $S\text{-}J^c$ closed set in (G, τ_E) . Hence, m is $S\text{-}J^c$ continuous.
3. Consider the mapping $m: (G, \tau_E) \rightarrow (H, \sigma_K)$ is $s\text{-}\alpha$ -continuous. Since all $s\text{-}\alpha$ -closed set are $S\text{-}J^c$ closed set. Then for each s -closed set (α_K) in (H, σ_K) , $m^{-1}(\alpha_K)$ is $S\text{-}J^c$ closed set in (G, τ_E) . Hence, m is $S\text{-}J^c$ continuous.

Example 3.4: Consider $G = \{1,2\}$, $E = \{e_1, e_2\}$, $\tau = \{\tilde{\phi}, \tilde{G}, \delta_{E1}, \delta_{E2}, \delta_{E3}\}$ where $\delta_1(e_1) = 1$, $\delta_1(e_2) = \tilde{\phi}$, $\delta_2(e_1) = \tilde{\phi}$, $\delta_2(e_2) = 1$, $\delta_3(e_1) = 1$, $\delta_3(e_2) = 1$; $H = \{3,4\}$, $K = \{k_1, k_2\}$, $\sigma = \{\tilde{\phi}, \tilde{H}, (\vartheta_{K1}), (\vartheta_{K2}), (\vartheta_{K3})\}$ where $\vartheta_1(k_1) = \tilde{\phi}$, $\vartheta_1(k_2) = 3$, $\vartheta_2(k_1) = \tilde{\phi}$, $\vartheta_2(k_2) = 4$, $\vartheta_3(k_1) = \tilde{\phi}$, $\vartheta_3(k_2) = (3,4)$. Define $u: G \rightarrow H$ and $v: E \rightarrow K$ as $u(1) = 4, u(2) = 3$. Consider $m: (G, \tau_E) \rightarrow (H, \sigma_K)$ is a s -mapping where (R_K) is s -closed set in (H, σ_K) then $m^{-1}(R_K) = \{(e_1, 1, 2), (e_2, 1)\}$ is $S\text{-}J^c$ closed set and it is not s -closed set, s -semi-closed set and $s\text{-}\alpha$ -closed set. Hence, m is $S\text{-}J^c$ continuous and it is not s -continuous, s -semi-continuous and $s\text{-}\alpha$ -continuous.

Theorem 3.5: A s -map m from (G, τ_E) to (H, σ_K) be a s -semi*-continuous. Then it is $S\text{-}J^c$ continuous and the converse is not true. Also $s\text{-}\hat{g}$ continuous map is $S\text{-}J^c$ continuous map.

Proof: Consider $m: (G, \tau_E) \rightarrow (H, \sigma_K)$ is s -semi*-continuous. Since all s -semi*-closed set are $S\text{-}J^c$ closed set. Then for each s -closed set (S_K) in (H, σ_K) , $m^{-1}(S_K)$ is $S\text{-}J^c$ closed set in (G, τ_E) . Hence, m is $S\text{-}J^c$ continuous. Since $s\text{-}\hat{g}$ -closed sets are all $S\text{-}J^c$ closed set. Then for each s -closed set (A_K) in (H, σ_K) , the inverse image of (A_K) is $S\text{-}J^c$ closed set in (G, τ_E) . Hence, m is $S\text{-}J^c$ continuous.

Example 3.6: Consider $G = \{1,5\}$, $E = \{e_1, e_2\}$, $\tau = \{\tilde{\phi}, \tilde{G}, (I_E)\}$ where $I(e_1) = (1,5)$, $I(e_2) = \tilde{\phi}$; $H = \{2,8\}$, $K = \{k_1, k_2\}$, $\sigma = \{\tilde{\phi}, \tilde{H}, (J_{K1}), (J_{K2}), (J_{K3})\}$ where $J_1(k_1) = 8$, $J_1(k_2) = \tilde{\phi}$, $J_2(k_1) = \tilde{\phi}$, $J_2(k_2) = 2$, $J_3(k_1) = 8$, $J_3(k_2) = 2$. Define





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$u: G \rightarrow H$ and $v: E \rightarrow K$ as $u(1) = 8, u(5) = 2$. Let $m: (G, \tau_E) \rightarrow (H, \sigma_K)$ be a s-map where (T_K) is s-closed set in (H, σ_K) then $m^{-1}(T_K) = \{(e_1, 5), (e_2, 1)\}$ is $S\text{-}J^c$ closed set but not s-semi*-closed set and $s\text{-}\hat{g}$ closed set. Hence, m is $S\text{-}J^c$ continuous but it is not s-semi*-continuous and $s\text{-}\hat{g}$ continuous.

Theorem 3.7: Consider $m: (G, \tau_E) \rightarrow (H, \sigma_K)$ be a s-map. If

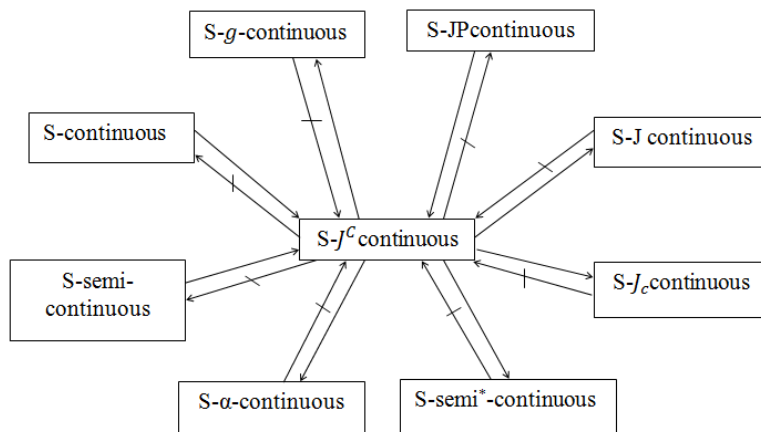
1. m is $S\text{-}J^c$ continuous then it is s-g continuous.
2. m is $S\text{-}J^c$ continuous then it is S-JP continuous.
3. m is $S\text{-}J^c$ continuous then it is S-J continuous.
4. m is $S\text{-}J^c$ continuous then it is $S\text{-}J_c$ continuous.

Proof

1. Consider $m: (G, \tau_E) \rightarrow (H, \sigma_K)$ is $S\text{-}J^c$ continuous. Since $S\text{-}J^c$ closed sets are all s-g closed set. Then for each s-closed set (U_K) in (H, σ_K) , $m^{-1}(U_K)$ is s-g closed set in (G, τ_E) . Hence, m is s-g-continuous.
2. Consider $m: (G, \tau_E) \rightarrow (H, \sigma_K)$ is $S\text{-}J^c$ continuous. Since all $S\text{-}J^c$ closed sets are S-JP closed set. Then for each s-closed set (W_K) in (H, σ_K) , $m^{-1}(W_K)$ is S-JP closed set in (G, τ_E) . Hence, m is S-JP continuous.
3. Consider $m: (G, \tau_E) \rightarrow (H, \sigma_K)$ is $S\text{-}J^c$ continuous. Since each $S\text{-}J^c$ closed set are S-J closed set. Then for each s-closed set (L_K) in (H, σ_K) , $m^{-1}(L_K)$ is S-J closed set in (G, τ_E) . Hence, m is S-J continuous.
4. Consider $m: (G, \tau_E) \rightarrow (H, \sigma_K)$ is $S\text{-}J^c$ continuous. Since each $S\text{-}J^c$ closed set are $S\text{-}J_c$ closed set. Then for each s-closed set (Q_K) in (H, σ_K) , $m^{-1}(Q_K)$ is $S\text{-}J_c$ closed set in (G, τ_E) . Hence, m is $S\text{-}J_c$ continuous.

Remark 3.8: S-g continuous, S-JP continuous, S-J continuous and $S\text{-}J_c$ continuous are not $S\text{-}J^c$ continuous.

Example 3.9: Consider $G = \{6,7\}$, $E = \{e_1, e_2\}$, $\tau = \{\tilde{\phi}, \tilde{G}, O_{E1}, O_{E2}\}$ where $O_1(e_1) = \tilde{\phi}$, $O_1(e_2) = 6$, $O_2(e_1) = 6, O_2(e_2) = 6$; $H = \{0,9\}$, $K = \{k_1, k_2\}$, $\sigma = \{\tilde{\phi}, \tilde{H}, P_{E1}, P_{E2}, P_{E3}\}$ where $P_1(k_1) = 9$, $P_1(k_2) = 9$, $P_2(k_1) = (0,9)$, $P_2(k_2) = 9$. Define $u: G \rightarrow H$ and $v: E \rightarrow K$ as $u(6) = 9, u(7) = 0$. Let $m: (G, \tau_E) \rightarrow (H, \sigma_K)$ is a s-mapping where (L_K) is s-closed set in (H, σ_K) then $m^{-1}(L_K) = \{(e_1, \tilde{\phi}), (e_2, 7)\}$ is s-g-closed set, S-JP closed set, S-J closed set and $S\text{-}J_c$ closed set but it is not $S\text{-}J^c$ closed set. Hence, m is s-g continuous, S-JP continuous, S-J continuous and $S\text{-}J_c$ continuous but not $S\text{-}J^c$ continuous.



Theorem 3.10: The two ST spaces are (G, τ_E) and (H, σ_K) where $\tilde{G} = M \tilde{\cap} N$. $S\text{-}J^c$ continuous maps $m: (M, \tau_{M_E}) \rightarrow (H, \sigma_K)$ and $n: (N, \tau_{N_E}) \rightarrow (H, \sigma_K)$ be such that $m(\alpha_E) = n(\alpha_E)$ for each $\alpha_E \in M_E \tilde{\cap} N_E$. Suppose that M_E and N_E are $S\text{-}J^c$ closed sets in (G, τ_E) then the combination $\gamma: (G, \tau_E) \rightarrow (H, \sigma_K)$ is $S\text{-}J^c$ continuous.

Proof: Consider (T_E) be any s-closed set in (H, σ_K) . Clearly, $\gamma^{-1}(T_E) = m^{-1}(T_E) \tilde{\cup} n^{-1}(T_E) = C_E \tilde{\cup} D_E$ where $C_E = m^{-1}(T_E)$ and $D_E = n^{-1}(T_E)$. But C_E is $S\text{-}J^c$ closed in M_E and M_E is $S\text{-}J^c$ closed in (G, τ_E) and so C_E is $S\text{-}J^c$ closed in (G, τ_E) .





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Similarly, D_E is $S\text{-}J^c$ closed in (G, τ_E) . Therefore, $C_E \cup D_E$ is $S\text{-}J^c$ closed in (G, τ_E) . Thus $\gamma^{-1}(T_E)$ is $S\text{-}J^c$ closed in (G, τ_E) . Hence, γ is $S\text{-}J^c$ continuous.

Remark 3.11: Consider $m: (G, \tau_E) \rightarrow (H, \sigma_K)$ be a $S\text{-}J^c$ continuous map. Then for each $(g_e) \in (G, \tau_E)$ and each s -open set $(V_K) \in (H, \sigma_K)$ containing $m(g_e)$, there exists $(Z_E) \in m^{-1}(V_K)$ such that $(g_e) \in (Z_E)$, $m(Z_E) \subseteq (V_K)$.

Theorem 3.12: For a subset (S_E) of a ST space (G, τ_E) the subsequent statements are relevant.

1. $SJ^c O(G, \tau_E)$ is closed under any union.
2. (S_E) is $S\text{-}J^c$ closed iff $SJ^c cl(S_E) = (S_E)$.
3. (S_E) is $S\text{-}J^c$ open iff $SJ^c int(S_E) = (S_E)$.

Proof: $1 \Rightarrow 2$ Consider (S_E) be a $S\text{-}J^c$ closed set in the ST space (G, τ_E) . Then by definition of $S\text{-}J^c$ closure, $SJ^c cl(S_E) = (S_E)$. Conversely assume that $SJ^c cl(S_E) = (S_E)$, for each $(g_e) \in (S_E)^c$, $(g_e) \notin SJ^c cl(S_E)$, therefore there exists a $S\text{-}J^c$ open set $(X_E)_{(g_e)}$ such that $(X_E)_{(g_e)} \cap (S_E) = \emptyset$ and thus $(g_e) \in (X_E)_{(g_e)} \subseteq (S_E)^c \therefore (S_E)^c = \cup (X_E)_{(g_e)}$. Then by (1), $(S_E)^c$ is $S\text{-}J^c$ open. Hence (S_E) is $S\text{-}J^c$ closed.

$2 \Rightarrow 3$ Consider (S_E) be a $S\text{-}J^c$ open set, then $(S_E)^c$ is a $S\text{-}J^c$ closed set. Therefore, $SJ^c cl((S_E)^c) = (S_E)^c$ by hypothesis $(SJ^c cl((S_E)^c))^c = (S_E)$. That is $SJ^c int(S_E) = (S_E)$.

$3 \Rightarrow 1$ Consider $\{(U_E)_\alpha : \alpha \in \Lambda\}$ be a family of $S\text{-}J^c$ open sets of (G, τ_E) . Take $(U_E) = \{\bigcup_\alpha (U_E)_\alpha\}$, for each $(g_e) \in (U_E)$ there exists $\alpha(g_e) \in \Lambda$ such that $(g_e) \in (U_E)_{\alpha(g_e)} \subseteq (U_E)$. Because $(g_e) \in (U_E)_{\alpha(g_e)}$ is $S\text{-}J^c$ open, $(g_e) \in SJ^c int(U_E)$ and so $(U_E) = SJ^c int(U_E)$. By (3), (U_E) is $S\text{-}J^c$ open. Thus $SJ^c O(G, \tau_E)$ is closed under any union.

Theorem 3.13: If $m: (G, \tau_E) \rightarrow (H, \sigma_K)$ is $S\text{-}J^c$ continuous map and $n: (H, \sigma_K) \rightarrow (W, \rho_R)$ is s -continuous map. Then $g \circ f: (G, \tau_E) \rightarrow (W, \rho_R)$ is $S\text{-}J^c$ continuous map.

Proof: Consider (Q_R) be a s -closed set of (W, ρ_R) . Implies $n^{-1}(Q_R)$ is s -closed in (H, σ_K) . $\therefore m^{-1}(n^{-1}(Q_R)) = (n \circ m)^{-1}(Q_R)$ is $S\text{-}J^c$ closed in (G, τ_E) because m is $S\text{-}J^c$ continuous. Thus $n \circ m$ is $S\text{-}J^c$ continuous.

S-J^c IRRESOLUTE MAP

Definition 4.1: A s -map $m: (G, \tau_E) \rightarrow (H, \sigma_K)$ is said to be **S-J^c irresolute map** if $m^{-1}(A_K)$ is $S\text{-}J^c$ closed set in (G, τ_E) for each $S\text{-}J^c$ closed set (A_K) in (H, σ_K) .

Theorem 4.2: A s -map $m: (G, \tau_E) \rightarrow (H, \sigma_K)$ is $S\text{-}J^c$ irresolute if $m^{-1}(P_K)$ is $S\text{-}J^c$ open set in (G, τ_E) for each $S\text{-}J^c$ open set (P_K) in (H, σ_K) .

Proof: Consider $m: (G, \tau_E) \rightarrow (H, \sigma_K)$ be a $S\text{-}J^c$ irresolute and (P_K) be $S\text{-}J^c$ open set in (H, σ_K) . Then $m^{-1}(P_K)^c$ is $S\text{-}J^c$ closed set in (G, τ_E) . Hence, $m^{-1}(P_K)$ is $S\text{-}J^c$ open set in (G, τ_E) .

Theorem 4.3: If a s -map $m: (G, \tau_E) \rightarrow (H, \sigma_K)$ be a $S\text{-}J^c$ irresolute map then it is $S\text{-}J^c$ continuous map and the $S\text{-}J^c$ continuous map cannot be $S\text{-}J^c$ irresolute map.

Proof: Consider $m: (G, \tau_E) \rightarrow (H, \sigma_K)$ be a $S\text{-}J^c$ irresolute map and (O_K) be s -closed set in (H, σ_K) . Then $m^{-1}(O_K)$ is $S\text{-}J^c$ closed set in (G, τ_E) . Since, all s -closed sets are $S\text{-}J^c$ closed set. Hence, m is $S\text{-}J^c$ continuous map.

Example 4.4: Consider $G = \{\alpha, \beta\}$, $E = \{e_1, e_2\}$, $\tau = \{\tilde{\phi}, \tilde{G}, (\lambda_{E1}), (\lambda_{E2}), (\lambda_{E3})\}$ where $\lambda_1(e_1) = \alpha$, $\lambda_1(e_2) = \tilde{\phi}$, $\lambda_2(e_1) = \tilde{\phi}$, $\lambda_2(e_2) = \alpha$, $\lambda_3(e_1) = \alpha$, $\lambda_3(e_2) = \alpha$; and $H = \{1, 2\}$, $K = \{k_1, k_2\}$, $\sigma = \{\tilde{\phi}, \tilde{H}, (Y_{K1}), (Y_{K2}), (Y_{K3})\}$ where $Y_1(k_1) = \tilde{\phi}$, $Y_1(k_2) = 1$, $Y_2(k_1) = \tilde{\phi}$, $Y_2(k_2) = 2$, $Y_3(k_1) = \tilde{\phi}$, $Y_3(k_2) = 1, 2$. Define $u: G \rightarrow H$ and $v: E \rightarrow K$ as $u(\alpha) = 2, u(\beta) = 1$. Let $m: (G, \tau_E) \rightarrow (H, \sigma_K)$ is a s -mapping where (T_K) is $S\text{-}J^c$ closed set in (H, σ_K) then $m^{-1}(T_K) = \{(e_1, \alpha), (e_2, \alpha)\}$ is not $S\text{-}J^c$ closed set in (G, τ_E) . Hence, m is not $S\text{-}J^c$ irresolute.





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Theorem 4.5: Consider $m: (G, \tau_E) \rightarrow (H, \sigma_K)$ be a soft map. Suppose

1. m is $S\text{-}J^c$ irresolute then it is $S\text{-}JP$ irresolute.
2. m is $S\text{-}J^c$ irresolute then it is $S\text{-}J$ irresolute.
3. m is $S\text{-}J^c$ irresolute then it is $S\text{-}J_c$ irresolute

Proof

1. Consider $m: (G, \tau_E) \rightarrow (H, \sigma_K)$ is $S\text{-}J^c$ irresolute. Since all $S\text{-}J^c$ closed sets are $S\text{-}JP$ closed set. Then for each $S\text{-}JP$ closed set (β_K) in (H, σ_K) , $m^{-1}(\beta_K)$ is $S\text{-}JP$ closed set in (G, τ_E) . Hence, m is $S\text{-}JP$ irresolute.
2. Consider $m: (G, \tau_E) \rightarrow (H, \sigma_K)$ is $S\text{-}J^c$ irresolute. Since all $S\text{-}J^c$ closed sets are $S\text{-}J$ closed set. Then for each $S\text{-}J$ closed set (γ_K) in (H, σ_K) , $m^{-1}(\gamma_K)$ is $S\text{-}J$ closed set in (G, τ_E) . Hence, m is $S\text{-}J$ irresolute.
3. Consider $m: (G, \tau_E) \rightarrow (H, \sigma_K)$ is $S\text{-}J^c$ irresolute. Since all $S\text{-}J^c$ closed sets are $S\text{-}J_c$ closed set. Then for each $S\text{-}J_c$ closed set (δ_K) in (H, σ_K) , $m^{-1}(\delta_K)$ is $S\text{-}J_c$ closed set in (G, τ_E) . Hence, m is $S\text{-}J_c$ irresolute.

Remark 4.6: $S\text{-}JP$ irresolute, $S\text{-}J$ irresolute and $S\text{-}J_c$ irresolute are not $S\text{-}J^c$ irresolute.

Example 4.7: Consider $G = \{\mu_1, \mu_2\}$, $E = \{e_1, e_2\}$, $\tau = \{\tilde{\phi}, \tilde{G}, (S_{E1}), (S_{E2})\}$ where $S_1(e_1) = \tilde{\phi}$, $S_1(e_2) = \mu_1$, $S_2(e_1) = \mu_1$, $S_2(e_2) = \mu_1$; $H = \{\nu_1, \nu_2\}$, $K = \{k_1, k_2\}$, $\sigma = \{\tilde{\phi}, \tilde{H}, L_{K1}, (L_{K2}), (L_{K3})\}$ where $L_1(k_1) = \nu_2$, $L_1(k_2) = \nu_2$, $L_2(k_1) = (\nu_1, \nu_2)$, $L_2(k_2) = \nu_2$. Define $u: G \rightarrow H$ and $v: E \rightarrow K$ as $u(\mu_1) = \nu_2, u(\mu_2) = \nu_1$. Let $m: (G, \tau_E) \rightarrow (H, \sigma_K)$ is a s -mapping where (θ_K) is $S\text{-}JP$ closed set, $S\text{-}J$ closed set and $S\text{-}J_c$ closed set in (H, σ_K) then $m^{-1}(\theta_K) = \{(e_1, \phi), (e_2, \mu_2)\}$ is $S\text{-}JP$ closed set, $S\text{-}J$ closed set and $S\text{-}J_c$ closed set but it is not $S\text{-}J^c$ closed set. Hence, m is $S\text{-}JP$ irresolute, $S\text{-}J$ irresolute and $S\text{-}J_c$ irresolute but not $S\text{-}J^c$ irresolute.

Definition 4.8: A ST space (G, τ_E) is known as $S\text{-}T_{J^c}$ space if each $S\text{-}J^c$ closed set is S -closed.

Theorem 4.9: Consider the ST space (G, τ_E) and $S\text{-}T_{J^c}$ space (H, σ_K) , m be a s -map from (G, τ_E) to (H, σ_K) . Then the subsequent statements are relevant.

1. m is $S\text{-}J^c$ irresolute.
2. m is $S\text{-}J^c$ continuous.

Proof: $1 \Rightarrow 2$ Consider (μ_K) be a s -closed set in (H, σ_K) . Then $m^{-1}(\mu_K)$ is $S\text{-}J^c$ closed set in (G, τ_E) because all s -closed sets are $S\text{-}J^c$ closed set. Hence, m is $S\text{-}J^c$ continuous.

$2 \Rightarrow 1$ Consider (μ_K) be a $S\text{-}J^c$ closed set in (H, σ_K) . Then (μ_K) is a s -closed set in (H, σ_K) because (H, σ_K) is a $S\text{-}T_{J^c}$ space which implies $m^{-1}(\mu_K)$ is $S\text{-}J^c$ closed in (G, τ_E) . Therefore, m is $S\text{-}J^c$ irresolute.

Theorem 4.10: Consider $m: (G, \tau_E) \rightarrow (H, \sigma_K)$ and $n: (H, \sigma_K) \rightarrow (W, \rho_R)$ be any two s -maps. Then $n \circ m$ is $S\text{-}J^c$ continuous if m is $S\text{-}J^c$ irresolute and n is $S\text{-}J^c$ continuous.

Proof: Consider (P_K) be a s -closed set in (W, ρ_R) . Then n is $S\text{-}J^c$ continuous because n is $S\text{-}J^c$ irresolute which implies $m^{-1}(P_K)$ is $S\text{-}J^c$ closed set in (G, τ_E) . Hence, $n \circ m$ is $S\text{-}J^c$ continuous.

Theorem 4.11: The two s -maps are $m: (G, \tau_E) \rightarrow (H, \sigma_K)$ and $n: (H, \sigma_K) \rightarrow (W, \rho_R)$. Then

1. $n \circ m: (G, \tau_E) \rightarrow (W, \rho_R)$ is $S\text{-}J^c$ continuous if m is $S\text{-}J^c$ continuous and n is s -continuous.
2. $n \circ m: (G, \tau_E) \rightarrow (W, \rho_R)$ is $S\text{-}J^c$ irresolute if m is $S\text{-}J^c$ irresolute and n is $S\text{-}J^c$ irresolute.

Proof

1. Consider (I_R) be a s -closed set in (W, ρ_R) . Then $n^{-1}(I_R)$ is s -closed set in (H, σ_K) subsequently, n is s -continuous and m is $S\text{-}J^c$ continuous. $\therefore m^{-1}(n^{-1}(I_R))$ is $S\text{-}J^c$ closed set in (G, τ_E) . Thus $n \circ m$ is $S\text{-}J^c$ continuous.
2. Consider (J_R) be a $S\text{-}J^c$ closed set in (W, ρ_R) . Then $n^{-1}(J_R)$ is $S\text{-}J^c$ closed set in (H, σ_K) because n is $S\text{-}J^c$ irresolute. Subsequently, m is $S\text{-}J^c$ irresolute, $m^{-1}(n^{-1}(J_R))$ is $S\text{-}J^c$ closed set in (G, τ_E) . Thus $n \circ m$ is $S\text{-}J^c$ irresolute.





CONCLUSION

This paper provides a thorough description of $S\text{-}J^c$ continuous map and $S\text{-}J^c$ irresolute map, comparing them with other existing s -mappings in certain cases. In addition, the paper explores several fundamental theorems and observations related to these mappings, which can help future researchers in real-life applications, particularly in medical diagnosis. Overall, this paper offers valuable insights into the properties of these mappings and their potential applications in various fields.

REFERENCES

1. A. Selvi & I. Arockiarani, "On Soft Almost g -Continuous Function", *International Journal of Mathematical Research*, Vol. 7, no. 2, pp. 109-123, 2015.
2. C. G. Aras and H. Cakalli, "On Soft Mappings", arXiv:1305.4545v1[math.GM], 16 May 2013.
3. D. Molodtsov, "Soft Set Theory First Results", *Computers and Mathematics with Applications*, Vol. 37, pp. 19-31, 1999.
4. K. Indirani & M.G. Smitha, "On Soft RGB-continuous functions in Soft Topological Spaces", *International Journal of Physics and Mathematical Sciences*, Vol. 4 (3), pp. 78-86, 2014.
5. K. Kannan, D. Rajalakshmi, Gopikrishnan, R. Janani & M. Madhumitha, "Soft s^*g -continuous functions", *International Journal of Pure and Applied Mathematics*, Vol. 6, pp. 51-61, 2018.
6. M. Shabir and M. Naz, "On Soft Topological Spaces", *Computers and Mathematics with Applications*, Vol. 61, pp. 1786-1799, 2011.
7. P.K. Maji, R. Biswas and A.R. Roy, "Soft Set Theory", *Computers and Mathematics with Applications*, Vol. 45, no. 4-5, pp. 555-562, 2003.
8. S. Jackson, J. Carlin & S. Chitra, "Some New Results in Soft Topological Spaces", (Communicated).
9. S. Jackson, S. Pious Missier and P. Anbarasi Rodrigo, "Soft Strongly JP Continuous Functions", *Global Journal of Pure and Applied Mathematics*, ISSN 0973-1768 Vol. 13, No. 5, pp. 27-35, 2017.
10. S. Pious Missier & S. Jackson, "On Soft JP Continuous Mappings", *Global Journal of Pure and Applied Mathematics*, Vol. 13, pp. 6723-6736, 2017.





Antioxidant Potential of *Caesalpinia sappan* Linn. Protects Indomethacin Induced Enterocolitis in Rats

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ABSTRACT

To evaluate the potential of hydroalcoholic heartwood extract of *Caesalpinia sappan* to protect against indomethacin-induced enterocolitis in rats. The rats were randomly divided into seven groups (n=6). Group I received 0.3% w/v of sodium carboxy methyl cellulose, p.o. (normal control), group II received HAECs alone 400 mg/kg, p.o. (extract alone), group III received Indomethacin 7.5 mg/kg, s.c. (disease control), groups IV, V, and VI received HAECs 150, 200 & 400 mg/kg, p.o. respectively and group VII received sulfasalazine 100 mg/kg, p.o. (standard control). All the groups except groups I and II, received respective treatments for 7 consecutive days before induction of indomethacin on the days 8 and 9 and the treatment was continued until the 11th day. Macroscopic scoring and histological analysis were used to evaluate the development of ulcers in the ileum. Additionally, intestinal oxidative stress parameters such as catalase (CAT), superoxide dismutase (SOD), reduced glutathione (GSH), total protein, myeloperoxidase (MPO), nitric oxide (NO), and serum lactate dehydrogenase (LDH) were assessed. HAECs treatment showed significantly attenuated indomethacin-induced ileal damage, reduction in serum LDH, tissue MPO, LPO, macroscopic score, nitric oxide levels, and increased levels of CAT, SOD, GSH, and total protein levels. Further, the observed activity of HAECs was well correlated with histopathological alterations. **Conclusion:** Our findings demonstrated that the hydroalcoholic heartwood extract of *Caesalpinia sappan* afforded protection against enterocolitis induced by indomethacin. This protective effect may be owed to its antimicrobial, antioxidant, antiulcer, and anti-inflammatory properties.





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Keywords: Inflammatory bowel disease, Crohn's disease, Oxidative stress, Sulfasalazine.

INTRODUCTION

IBD (inflammatory bowel illnesses) is the aggregate term for ulcerative colitis (UC) and Crohn's disease (CD) as chronic inflammatory gastrointestinal disorders [1]. In CD, the inflammation can affect any region of the intestine and is frequently transmural and discontinuous, while ulcerative colitis is typically continuous, superficial, and limited to the mucosa of the colon and rectum [2]. Though the precise etiology of IBD is unknown, it is believed to be complex and may involve oxidative stress, dysregulated immune response, microbial infections, increased levels of inflammatory mediators, environmental factors, and genetics [3]. The initiation and progression of this illness are significantly influenced by inflammatory mediators, including reactive oxygen metabolites, eicosanoids, and cytokines [4]. Reactive nitrogen species (RNS) and reactive oxygen species (ROS) are produced by oxygen metabolism, which is essential for mammalian cell viability [5]. The GI tract mucosal layer's intracellular damage is mostly caused by two prominent mediators-ROS and RNS. Activation of the oxidative stress-responsive gene, which is essential for the onset and progression of inflammatory bowel disease (IBD), is triggered by cytokines such as TNF- α , IL-1 β , IL-6, and IL-8 that are generated from macrophages [6]. RNS up-regulates the expression of genes involved in innate and adaptive immune responses in the GI tract and bacterial invasion, which in turn stimulates the immune response and initiates IBD [7]. *Caesalpinia sappan* Linn. (Fabaceae/Caesalpinaceae) is being used traditionally for various medical benefits. The heartwood contains various anti-inflammatory and rich anti-oxidant chemical constituents such as triterpenoids and steroids (lupeol, β -amyrin, cycloartenol), xanthone, flavones, anthraquinones (brazilin, brazilein, sappanone A), phenolic acids (chlorogenic acid, caffeic acid, gallic acid), alkaloids and tannins (sappan chalcone, sappanone B) [8]. The heartwood extract of *Caesalpinia sappan* Linn. has been reported to possess an array of pharmacological activities including anti-inflammatory, antioxidant, anti-ulcer, hepato-protective [9], and antimicrobial activities [10]. Accordingly, the present study was designed to explore the effect of *Caesalpinia sappan* Linn. against indomethacin-induced enterocolitis in rats.

MATERIALS AND METHODS

Extraction of plant material

The hydroalcoholic extract of dried heartwood of *Caesalpinia sappan* Linn. was prepared by taking the powder in 80% (v/v) ethanol and this condition was maintained for 72 hours. Then the residues were separated using a vacuum filter and the solvent obtained was concentrated to the dry mass using a vacuum evaporator. The residue was dried in desiccators and stored for further use [11].

Experimental animals

Male albino Wistar rats (200-250 g) were used for the present study. The animals were collected from the Sree Siddaganga College of Pharmacy animal house, Tumkur (SSCPT/IAEC.Clear/183/18-19). The animals were maintained under controlled conditions of temperature (22 ± 2 °C), humidity ($50 \pm 5\%$) and 12 h light-dark cycles. The acclimatized animals were randomized into experimental and control groups and housed individually in sanitized polypropylene cages containing sterile paddy husk as bedding. They had free access to standard pellets as a basal diet and water ad libitum.

Experimental design: [12, 13, 14]

The animals were randomly divided into seven groups, containing six animals in each. Group 1 served as a normal control and received 0.3 % w/v of sodium CMC. Group 2 was pre-treated with HAECs 400 mg/kg, p.o. (extract control). Group 3 was indomethacin control and received 7.5 mg/kg s.c. indomethacin. Groups 4, 5, and 6 served as HAECs pre-treatment groups that received HAECs at doses of 150, 200, and 400 mg/kg, p.o. respectively. Group 7 served as SLZ standard treatment group, and received Sulfasalazine (SLZ) in a dose of 100mg/kg, p.o. Animals were



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pre-treated with HAECs for 7 days. The Indomethacin (7.5 mg/kg, s.c.) was given on the 8th and 9th day of treatment. The respective treatments were continued till the 11th day. After overnight fasting, on the 12th day after treatment, the animals were anaesthetized and blood was withdrawn by retro-orbital puncture to assess serum LDH. Later animals were sacrificed and dissected. The ileum was flushed with saline and cut open longitudinally. Inflammation was assessed based on the macroscopic score, oxidative stress parameters and histopathological studies.

Statistical Analysis

Results were expressed as mean \pm SEM. The statistical significance of any difference in each parameter among the groups was evaluated by one-way ANOVA, using the Tukey multiple comparisons test as post hoc test.

RESULTS**Macroscopic Score**

Macroscopic Scores (indicative of tissue damage) were significantly ($P < 0.001$) increased with two subsequent doses of Indo (7.5 mg/kg) in inducer control rats, as compared to normal control. Animals pre-treated with HAECs (150, 200 and 400mg/kg) for seven days before Indo intoxication exhibited significant ($P < 0.001$, $P < 0.001$ and $P < 0.001$ respectively) reduction compared to Indo alone treated rats. In addition, SLZ treatment (100 mg/kg) showed better results than the test extract as evident by higher protection by 50%. Pre-treatment of HAECs showed a higher percentage of protection (70.23%) compared to other tested doses. The standard sulphasalazine treatment showed 83.42% protection. (Table 1 & Figure 1).

Serum LDH level

The serum LDH, a marker of necrosis was found to be significantly ($P < 0.001$) increased in colitis control compared with normal control. In the case of pre-treatment of three doses of HAECs (150, 200 and 400 mg/kg, p.o.) and standard sulphasalazine exhibited a significant ($P < 0.01$) decrease in LDH level ($P < 0.001$, $P < 0.01$, $P < 0.001$ and $P < 0.001$ respectively) when compared to colitis control rats (Table 1 & Figure 2).

MPO activity

The activity of myeloperoxidase (MPO), the marker of neutrophil infiltration was significantly ($P < 0.001$) elevated in Indo alone administered group when compared to the normal control group. The HAECs (150, 400mg/kg, p.o.) administered groups showed significantly ($P < 0.01$, $P < 0.01$) decreased MPO activity as compared to Indo alone treated rats. Sulphasalazine (100mg/kg) significantly protected the rats against indomethacin-induced neutrophil infiltration in the damaged tissue as evident by lower MPO activity. (Table 1 & Figure 2).

Effect of HAECs on intestinal oxidative stress parameters

Rats treated with Indo (7.5mg/kg, s.c.) alone showed a significant ($P < 0.001$) decrease in SOD, CAT, GSH and an increase in intestinal MDA contents when compared to the respective levels in control rats treated with vehicle alone indicating oxidative stress. Rats pre-treated with HAECs (150, 200 and 400 mg/kg, p.o.) for 7 days prior to Indo administration showed significantly ($P < 0.05$, $P < 0.05$ and $P < 0.01$) enhanced levels of endogenous antioxidants and decreased levels of the intestinal MDA ($P < 0.001$) contents when compared to Indo alone treated rats indicating the defence against lipid peroxidation, SLZ pre-treated rats also showed significant preserved levels of SOD ($P < 0.01$), CAT ($P < 0.001$) and GSH ($P < 0.001$) reduction in intestinal MDA contents (Figure 2).

Measurement of Total protein in Ileum tissue

The protein content in the ileum of rats pre-treated with HAECs (200 and 400 mg /kg, p.o.) was significantly ($P < 0.01$ and $P < 0.001$ respectively) increased and the standard reference of sulphasalazine-treated rats showed significantly ($P < 0.001$) increased contents of total protein. No significant changes in tissue protein content of the ileum were observed between the normal control and HAECs (400 mg/kg) alone group (Table 2).



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The indo-alone treated toxicant control group showed a significant ($P < 0.001$) augment in the nitric oxide levels as compared to the normal control group. HA ECS (150, 200 and 400mg/kg, p.o.) and Sulphasalazine (7.5 mg/kg, p.o.) pre-treated groups showed significant ($P < 0.05$, $P < 0.05$, $P < 0.001$ and $P < 0.001$ respectively) decline in the tissue nitric acid level (Table 2).

Histopathological observations

Figure 3. Represents the histopathological features of normal rat colon showing normal mucosa and with all the intestinal layers distinctly visible with no abnormalities (Fig.3 & Table 3).

The Indo-induced rats showed severe ulceration in the colonic mucosa, transmural necrosis, oedema and inflammatory infiltrates in the mucosa layer (Fig. 3). In rats pre-treated with HA ECS (150, 200 and 400mg/kg) significantly attenuated the extent and severity of the histological signs of cell damage. Restoration of the intestinal epithelial surface was observed in the case of standard treatment with SLZ (100 mg/kg) (Fig. 3 & Table 3).

DISCUSSION

The present investigation outlines the anti-inflammatory and anti-oxidant activities of HA ECS against experimental models of IBD, such as Indo-induced enterocolitis in rats. Acute transmural inflammation of the small intestine is caused by the non-steroidal anti-inflammatory drug indomethacin and is characterized by wall thickening, mesenteric hemorrhage, and numerous mucosal ulcers [15]. In the present study, Indo produced hyperemia, hemorrhagic spots, bowel thickening, and gross ulceration with skip lesions mostly in the proximal ileum. Treatment with HA ECS and SLZ showed reduced intensity of lesions as evident by the lesser macroscopic score. The reduction in mucosal injury and inflammation with HA ECS treatment may be due to the enhancement of muco-protective PGs synthesis or its antibacterial and membrane stabilizing activity. The mechanism of development of disease in indomethacin-induced enterocolitis involves the role of protective prostaglandins and intestinal pathogens. The HA ECS might have exerted its effect due to its anti-inflammatory, antioxidant, cytoprotective, and antimicrobial properties [16, 17]. When cells are damaged, the cytoplasmic enzyme LDH is released into the bloodstream. Hence elevated serum LDH is a marker of tissue injury. Increased serum LDH levels were observed after Indo treatment, whereas HA ECS and SLZ treatment attenuation in the elevation of LDH, hence indicating the amelioration of tissue injury [18]. MPO is an enzyme that is present in neutrophil granulocytes and is released when the cells are activated by inflammatory stimuli. It is therefore a biochemical indicator of neutrophil infiltration.

Neutrophils play a critical role in the pathophysiology of IBD by producing a wide range of reactive oxygen species and superoxide anions, which in turn amplify the production of hydroxyl radicals and peroxides, which worsen tissue necrosis and mucosal dysfunction [19]. All the doses of HA ECS significantly reduced the MPO activity compared to the Indo alone group demonstrating the inhibition of infiltration of inflammatory cells responsible for disease progression. A major factor in the development of IBD is oxidative stress, which is an imbalance between reactive oxygen species (ROS) and antioxidant defense [20]. Tissue non-enzymatic antioxidant GSH plays a crucial role in scavenging ROS. Free radicals are known to attack lipid contents of cellular membranes leading to activation of the LPO process and cellular damage which is evident by the elevated LPO specific product like MDA in intestinal tissue [21]. The present study shows a decreased level of GSH and increased intestinal MDA contents followed by Indo-alone treatment indicating cellular oxidative injury and cytotoxicity. Animals pre-treated with HA ECS showed significantly preserved levels of GSH and reduced levels of MDA confirming that HA ECS decreased tissue damage and inflammation. SOD is a key enzyme that inactivates superoxide ion by transforming it into a more stable metabolite [22]. Catalase catalyzes the decomposition of hydrogen peroxide into water and oxygen [23]. HA ECS and SLZ treatment was able to preserve the levels of SOD and CAT in the ileum of respective groups. The protective effect of HA ECS against oxidative stress caused by Indo may be attributed to its antioxidant properties. The above facts are well correlated with histopathological findings, The ileum portion of Indo (7.5 mg/kg, s.c.) intoxicated rats showed the presence of massive inflammatory infiltrate cells in the mucosa, severely collapsed villi with a higher





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extent of inflammation and necrosis. Whereas, prior treatment with HAECS to the rats exhibited reduced damage as compared to Indo-alone administration. The *Caesalpinia sappan* Linn. has been reported to possess vital phytochemicals such as flavones, phenolic acids, brazilin, brazilin, sappanone A, alkaloids, and tannins. Such constituents are correlated to several health benefits, including antioxidant and anti-inflammatory properties. Therefore, the observed effect of the extract might be due to the abundance of any of the aforementioned constituents.

CONCLUSION

The current study reveals the protective action of hydroalcoholic heartwood extract of *Caesalpinia sappan* Linn. by alleviating the damage caused by indomethacin-induced enterocolitis in rats. This observed protective effect might be attributed to its anti-inflammatory and antioxidant potential. The outcomes of this investigation may have implications for future investigations using *Caesalpinia sappan* or its bioactive compounds as safe, natural, and efficacious therapies for individuals with inflammatory bowel disease.

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Conflict of Interest

The authors declare no potential conflict of interest.

REFERENCES

1. Wirtz S, Neurath MF. Mouse models of inflammatory bowel disease. *Adv Drug Deliv Rev.* 2007;59:1073-1083.
2. Abraham C, Cho JH. Inflammatory bowel disease. *N Engl J Med.* 2009; 361(21):2066-2078.
3. Babitha S, Bindu K, Nageena T, Veerapur VP. Fresh Fruit Juice of *Opuntia dillenii* Haw. Attenuates Acetic Acid-Induced Ulcerative Colitis in Rats. *J Diet Suppl.* 2019;16(4):431-442. doi: 10.1080/19390211.2018.1470128.
4. Pawar AT, Anap RM, Ghodasara JV, Kuchekar BS. Protective Effect of Hydroalcoholic Root Extract of *Rubia cordifolia* in Indomethacin-Induced Enterocolitis in Rats. *Indian J Pharm Sci.* 2011 Mar;73(2):250-253. doi: 10.4103/0250-474x.91577.
5. Hendrickson, B. A., Gokhale, R., & Cho, J. H. Clinical Aspects and Pathophysiology of Inflammatory Bowel Disease. *Clinical Microbiology Reviews.* 2002; 15(1), 79–94. doi:10.1128/cmr.15.1.79-94.
6. De Lange, K. M., & Barrett, J. C. Understanding inflammatory bowel disease via immune genetics. *Journal of Autoimmunity,* 2015; 64, 91–100. doi: 10.1016/j.jaut.2015.07.013
7. Molodecky, N. A., Soon, I. S., Rabi, D. M., Ghali, W. A., Ferris, M., Chernoff, G., Kaplan, G. G. Increasing Incidence and Prevalence of the Inflammatory Bowel Diseases with Time, Based on Systematic Review. *Gastroenterology,* 2012;142(1), 46–54. doi: 10.1053/j.gastro.2011.10.001
8. Vij T, Anil PP, Shams R, Dash KK, Kalsi R, Pandey VK, Harsányi E, Kovács B, Shaikh AM. A Comprehensive Review on Bioactive Compounds Found in *Caesalpinia sappan*. *Molecules.* 2023 Aug 25;28(17):6247. doi: 10.3390/molecules28176247.
9. Badami, S., Moorkoth, S., Rai, S. R., Kannan, E., & Bhojraj, S. Antioxidant Activity of *Caesalpinia sappan* Heartwood. *Biological & Pharmaceutical Bulletin,* 2003; 26(11), 1534–1537.
10. Srinivasan R, Karthik S, Mathivanan K, Baskaran R, Karthikeyan M, Gopi M, Govindasamy C. In vitro antimicrobial activity of *Caesalpinia sappan* L. *Asian Pacific Journal of Tropical Biomedicine.* 2012 Jan 1;2(1): S136-9.
11. Chellappan, D. R., Purushothaman, A. K., & Brindha, P. Gastroprotective potential of hydro-alcoholic extract of Pattanga (*Caesalpinia sappan* Linn.). *Journal of Ethnopharmacology.* 2017; 197, 294–305.





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12. Pawar AT, Anap RM, Ghodasara JV, Kuchekar BS. Protective Effect of Hydroalcoholic Root Extract of *Rubia cordifolia* in Indomethacin-Induced Enterocolitis in Rats. *Indian J Pharm Sci.* 2011;73(2):250-3.
13. Yamada T, Deitch E, Specian RD, Perry MA, Sartor RB, Grisham MB. Mechanisms of acute and chronic intestinal inflammation induced by indomethacin. *Inflammation.* 1993;17(6):641-662.
14. Jagtap AG, Shirke SS, Phadke AS. Effect of polyherbal formulation on experimental models of inflammatory bowel diseases. *J Ethnopharmacol.* 2004; 90:195–204.
15. Matsumoto S, Okabe Y, Setoyama H, Takayama K, Ohtsuka J, Funahashi H, Imaoka A, Okada Y, Umesaki Y. Inflammatory bowel disease-like enteritis and caecitis in a senescence-accelerated mouse P1/Yit strain. *Gut.* 1998 Jul; 43(1):71-78. doi: 10.1136/gut.43.1.71.
16. Basnet S, Adhikari A, Sachidananda VK, Thippeswamy BS, Veerapur VP. Protective effect of *Blumea lacera* DC aerial parts in indomethacin-induced enterocolitis in rats. *Inflammopharmacology.* 2015 Dec; 23:355-63.
17. Patil NR, Rasal VP, Malabade RH. Screening of mandarin oil on indomethacin induced inflammatory bowel disease in Wistar rats. *Indian Journal of Pharmaceutical Education and Research.* 2014 Oct 1;48 (Supplementary):1-6.
18. Terragni R, Morselli-Labate AM, Vignoli M, Bottero E, Brunetti B, Saunders JH. Is serum total LDH evaluation able to differentiate between alimentary lymphoma and inflammatory bowel disease in a real world clinical setting? *PloS one.* 2016 Mar17; 11(3):e0151641.
19. Szalai Z, Szász A, Nagy I, Puskás LG, Kupai K, Király A, Berkó AM, Pósa A, Strifler G, Baráth Z, Nagy LI. Anti-inflammatory effect of recreational exercise in TNBS-induced colitis in rats: role of NOS/HO/MPO system. *Oxidative Medicine and Cellular Longevity.* 2014.
20. Pavlick KP, Laroux FS, Fuseler J, Wolf RE, Gray L, Hoffman J, Grisham MB. Role of reactive metabolites of oxygen and nitrogen in inflammatory bowel disease. *Free Radical Biology and Medicine.* 2002 Aug 1;33(3):311-322.
21. Dodda D, Chhajer R, Mishra J. Protective effect of quercetin against acetic acid induced inflammatory bowel disease (IBD) like symptoms in rats: Possible morphological and biochemical alterations. *Pharmacological Reports.* 2014 Feb 1;66(1):169-173.
22. Kruidenier L, van Meeteren ME, Kuiper I, Jaarsma D, Lamers CB, Zijlstra FJ, Verspaget HW. Attenuated mild colonic inflammation and improved survival from severe DSS-colitis of transgenic Cu/Zn-SOD mice. *Free Radical Biology and Medicine.* 2003 Mar 15;34(6):753-765.
23. Pandey A, Verma S, Kumar VL. Metformin maintains mucosal integrity in experimental model of colitis by inhibiting oxidative stress and pro-inflammatory signalling. *Biomedicine and Pharmacotherapy.* 2017 Oct 1; 94:1121-1128.

Table 1. Effect of HA ECS pre-treatment on macroscopic score, Serum LDH and MPO in Indomethacin-induced enterocolitis in rats:

Groups	Macroscopic Scores (% of protection)	LDH(U/L)	MPO activity(U/g)
Normal Control	0.00±0.00	850.2±30.50	5.85±0.36
HA ECS alone (400 mg/kg, p.o.)	0.666±0.333	800.2±59.38	7.59±0.94
Indo alone (7.5mg/kg, s.c.)	14.17±0.7491 ^{###}	1329±39.57 ^{###}	13.08±8.950 ^{###}
Indo+ HA ECS (150 mg/kg, p.o.)	9.667±0.9189 ^{**} (35.64)	947.9±25.90 [*]	8.62±0.91 ^{**}
Indo+ HA ECS (200 mg/kg, p.o.)	8.333±0.4944 ^{***} (55.89)	866.9±21.35 ^{**}	9.69±0.63 [*]
Indo+ HA ECS (400 mg/kg, p.o.)	6.500±0.5627 ^{***} (70.23)	965.8±125.2 [*]	8.20±0.27 ^{**}
Indo + SLZ	4.500±0.4282 ^{***}	749.1±34.59 ^{**}	5.71±0.49 ^{***}





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(100 mg/kg, p.o.)	(83.42)		
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Table 2. Effect of HAECs pre-treatment on Total protein, CAT and Nitrite content in Indomethacin-induced enterocolitis in rats:

Groups	Total protein (mg/ml)	Nitrite content (µM/mg of tissue)
Normal Control	2.27±0.26	2.38±0.29
HAECs alone (400 mg/kg, p.o.)	2.64±0.53	2.18±0.22
Indo alone (7.5mg/kg, s.c.)	7.20±0.80 ^{###}	5.50±0.25 ^{###}
Indo+ HAECs (150 mg/kg, p.o.)	3.24±0.23 ^{***}	4.30±0.19
Indo + HAECs (200 mg/kg, p.o.)	4.12±0.32 ^{**}	3.70±0.22 [*]
Indo+ HAECs (400 mg/kg, p.o.)	5.60±0.21 [*]	3.30±0.20
Indo + SLZ (100 mg/kg, p.o.)	6.30±0.24 [*]	2.50±0.25 ^{**}

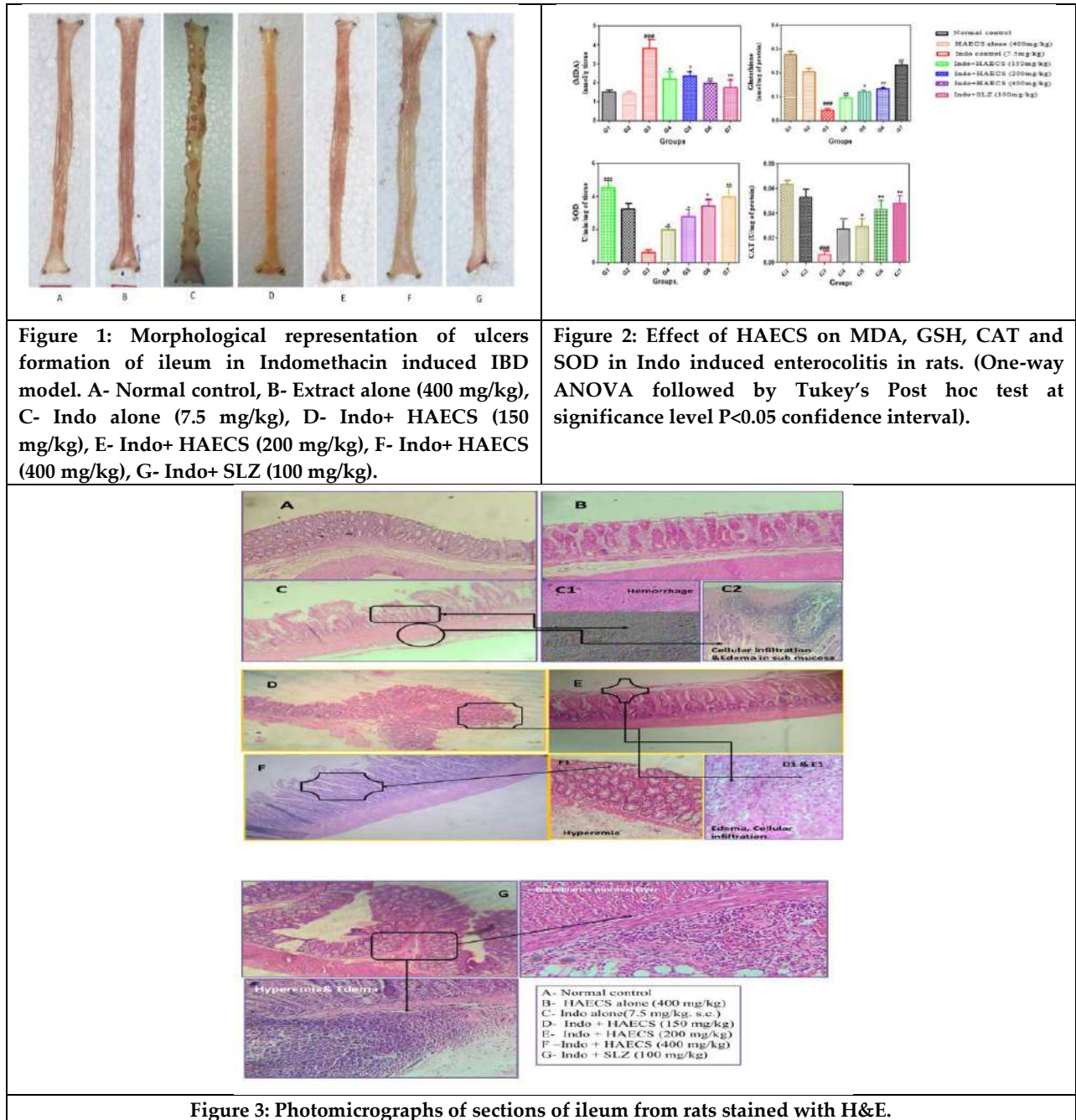
Table 3: Effect of different doses of HAECs on pathological changes in rat ileum.

Groups	Treatment	Ulceration	Hyperemia	Necrosis	Edema	Cellular Infiltration
I.	Normal control	Nil	Nil	Nil	Nil	Nil
II.	HAECs alone (400mg/kg, p.o.)	Nil	*	Nil	*	Nil
III.	Colitis control [Indomethacin 7.5 mg/kg, s.c.]	****	****	**	****	***
IV.	Indo + HAECs (150mg/kg, p.o.)	Nil	**	Nil	Nil	*
V.	Indo + HAECs (200 mg/kg, p.o.)	*	**	**	*	*
VI.	Indo + HAECs (400 mg/kg, p.o.)	*	**	*	*	Nil
VII.	Indo + SLZ (100 mg/kg, p.o.)	Nil	*	Nil	Nil	*





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Academic Achievement of Higher Secondary Students in Relation to their Self -Efficacy

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ABSTRACT

The present investigation was undertaken to study the Academic achievement of higher secondary students in relation to their self-efficacy. The researcher had selected 740 samples in district Anantnag, Jammu and Kashmir Union territory of India by adopting stratified random sampling. Self-efficacy scale constructed and validated by researchers were used in the study and for academic achievement, annual marks were collected from 12th class students in their previous class(11th). Pearson's product moment of coefficient of correlation were used to find out the relationship between academic achievement and self efficacy. The researcher also employed 't' test to find out the significance of mean difference between different demographical variables. The findings of the study revealed that there is a significant and positive relationship between the academic achievement and self efficacy. Further the study found that there exists significant difference of academic achievement and self efficacy with respect to Gender. no significant difference was found in the academic achievement and self efficacy of higher secondary students with respect to their locality and type of school. The researchers have determined that self-efficacy plays a significant role in improving academic performance. By boosting one's self-efficacy beliefs, individuals can progress toward effectiveness and excel academically.

Keywords: Academic achievement, Self -efficacy, Relation, Higher secondary students





INTRODUCTION

In the contemporary era, the pursuit of excellence and perfection is universal, with success being a coveted goal for all individuals. Among students, success is defined by academic accomplishments, which serve as foundational elements for future achievements. Achieving academic success is essential for fostering a child's holistic development and has consistently been a central focus of educational research, despite differing perspectives on the purpose of education. Academic achievement encompasses excellence across all academic disciplines, within the classroom, and through participation in extracurricular activities. Academic success serves as a measure of how effectively an individual has accomplished specific goals. Assessments, such as exams or continuous evaluations, are commonly employed to measure academic achievement. According to Good (1959), Academic achievement is defined as "the information obtained or abilities developed in the academic areas, typically assessed through test results or instructor evaluations." Achievement of the student may be influenced by several factors like study habits, intelligence, self-efficacy, socio-economic status, self-esteem, and parental support. One of the main factor that affects the achievement of the student is self efficacy. Self-efficacy refers to an individual's confidence in their capacity to accomplish a task or attain a goal. It involves the belief in one's ability to regulate their actions, have an impact on their surroundings, and sustain motivation while striving for their objective. According to Albert Bandura (1994), Self-efficacy is an individual's belief in their ability to effectively plan and execute the actions required to accomplish a goal. It influences people's behavior, emotions, thoughts, and motivation, guiding how they approach challenging situations with a sense of control. This confidence contributes to personal achievements and alleviates stress levels. Self-efficacy enhances academic achievement students by fostering a belief in their ability to succeed in academic tasks and challenges. Students with elevated self-efficacy tend to establish ambitious objectives and persevere despite challenges, and employ effective learning strategies. This confidence in their abilities enables them to approach their studies with a positive attitude, leading to increased motivation, engagement, and ultimately, higher levels of academic performance. Overall, self-efficacy plays a crucial role in shaping students' academic outcomes by influencing their thoughts, behaviours, and emotions related to learning.

NEED AND IMPORTANCE OF THE STUDY

In modern society, academic success holds great importance within the realms of education and the learning journey. It has become a crucial determinant of a child's future in today's highly competitive environment. Attaining academic success is considered the foremost goal for individuals across all societies. Students discover their skills, talents, and capabilities through academic achievements, which significantly shape their career aspirations. The connection between academic achievement and self-efficacy highlights the importance of individuals believing in their capabilities to succeed academically. When students possess high levels of self-efficacy, they are more likely to set challenging goals, persevere through difficulties, and utilize effective learning strategies. This confidence in their abilities not only enhances their academic performance but also fosters resilience in the face of setbacks. Additionally, self-efficacy influences students' motivation, engagement, and overall well-being, contributing to a positive learning experience. Therefore, recognizing and nurturing self-efficacy in students is essential for promoting academic success and fostering a supportive learning environment. Studies shows that there is a significant and positive correlation between Academic achievement and self-efficacy (Ahuja, A. 2016, Oyuga & Raburu 2019, Hasan and parvaiz 2019, Bhati K, Baral, R, & Meher, V 2022, Mahmood, Adnan, shazad, Shabir 2019). The existing literature has shown evidence of a correlation between students' academic achievement and self-efficacy. However, there is a lack of studies focusing on higher secondary students from the Kashmir Valley. Therefore, there is a need to investigate the relationship between academic achievement and self-efficacy of higher secondary students in the Kashmir Valley.





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REVIEW OF RELATED LITERATURE

Reviewing relevant literature allows the researcher to gain a thorough understanding of the study being undertaken, minimizing the risk of redundancy. It assists in identifying the variables, scope, and limitations of the topic. Additionally, it assures the researcher that the topic has been addressed previously and warrants further investigation. Moreover, it furnishes the researcher with comprehensive background knowledge concerning the relationships between variables and findings from prior relevant studies. The researches that has been done in the past, it can be said that higher the academic achievement, more will be the sense of self efficacy and vice versa, which means there is a positive relationship between academic achievement and self efficacy, the study further revealed that girls had statistically significant higher scores in self-efficacy, and academic achievement than boys (Ahuja, A 2016). Oyuga et al (2019) conducted a study on relationship between self efficacy and academic performance among secondary school students in Kenya and it was found that there is a positive relationship between self efficacy and achievement. In a study conducted by Hasan and Parvez (2019) titled "Effect of Self-Efficacy, Gender, and Locale on the Academic Achievement of Secondary School Students," a positive correlation was found between self-efficacy and academic performance. Additionally, self-efficacy was found to have no notable differing impact on academic achievement. Gender was identified as having a significant differing impact on self-efficacy. Furthermore, both gender and locale were observed to have significant differing effects on the academic achievement of secondary school students. Shkullaku (2013) conducted a study on gender difference in self-efficacy and academic performance among 180 Albanian students from two different universities. Results revealed a significant difference between male and female on self_efficacy. Bhati, etal (2022) studied academic self-efficacy and academic performance of undergraduate students in relation to gender and streams of education. The findings indicated that undergraduate students in the science stream exhibited elevated levels of academic self-efficacy and achieved higher academic performance in comparison to students in other streams. The results also indicated positive relationship between self-efficacy and academic achievement. Above given studies are related to the academic achievement and its relationship with self-efficacy, several investigations were undertaken to examine the influence of self-efficacy on the academic performance of students. However, no research was found focusing on higher secondary students in the Kashmir valley. Therefore, this study aims to address this gap in the literature

OBJECTIVES OF THE STUDY

- To study if any significant difference exists between academic achievement of higher secondary students with respect to their gender, locality and type of school
- To study if any significant difference exists between self-efficacy of higher secondary students with respect to their gender, locality and type of school
- To study the relationship between academic achievement and self- efficacy of higher secondary students.

Hypothesis

- There exists no significant difference in the academic achievement of higher secondary students with respect to their gender, locality and type of family.
- There exists no significant difference in the self-efficacy of higher secondary students with respect to their gender, locality and type of family.
- There is no significant relationship between academic achievement and self- efficacy of higher secondary students.

METHODOLOGY

Normative survey method was used to collect the data relevant for the study, Considering the objectives



**Aadil Hussain Mir and Sivakumar****Sample of the study**

Stratified random sampling method was used for the selection of a sample. A total of 740 secondary students were selected as sample for the study.

Statistical techniques used

In the present study, the following statistical techniques were used

Differential analysis ('t' test)

Correlation analysis

Tools Used**Self-efficacy scale**

Self efficacy scale constructed and validated by Aadil Hussain and R. Sivakumar (2023) were used in the study.

Academic achievement

Annual marks were collected from 12th standard students in their previous class (11th) examination conducted by JK BOSE. Results were systematically presented in the below mentioned tables.

Hypothesis1: There exists no significant difference in the academic achievement of higher secondary students with respect to their gender, locale and type of family. The results are shown in table 1,2 and 3.

Hypothesis 2: There exists no significant difference in the self-efficacy of higher secondary students with respect to their gender, locale and type of family. The results are shown in table 4,5 and 6.

Hypothesis 3: There is no significant relationship between academic achievement and self- efficacy of higher secondary students. The result is shown in table 7.

FINDINGS OF THE STUDY

- There is significant difference in the academic achievement of higher secondary students with respect to gender. Females are having high academic achievement than males.
- There is no significant difference in the academic achievement of higher secondary students with respect to their locality and type of school.
- There is significant difference in self-efficacy of higher secondary students with respect to gender. Female are having high sense of self-efficacy than males.
- There is no significant difference in self-efficacy of higher secondary students with respect to their locality and type of school.
- There exists significant and positive relationship between self-efficacy and academic achievement of higher secondary students.

DISCUSSION OF THE RESULTS

The primary focus of this study was to examine the relationship between academic achievement and self-efficacy among high school students in the Kashmir valley, recognizing self-efficacy as a key factor influencing academic achievement within the educational system. Self-efficacy, , plays a crucial role in enhancing academic achievement among secondary students. When students have high levels of self-efficacy, they tend to approach challenges with confidence and perseverance. They are more likely to set ambitious academic goals, exert effort to overcome obstacles, and persist in the face of setbacks. Additionally, students with high self-efficacy are more willing to engage in effective learning strategies, such as seeking help when needed, utilizing resources, and managing their time efficiently. As a result, they often perform better academically, as their belief in their own capabilities motivates them to strive for excellence and achieve their academic potential. Fostering self-efficacy in secondary students can lead to improved academic outcomes and a more positive learning experience. Like Ahuja (2016) examined that there is a significant and positive relationship between self-efficacy and academic achievement. Our result showed the same.



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As per this study, students having high sense of self-efficacy have high academic achievement and vice versa. Our findings have also support from different researches which conforms that academic achievement is directly proportional to self -efficacy or having positive relationship(Oyuga et al, 2019, Hasan and Parvez, 2019, Bhati et al 2022,Mahmood et al. 2019)

CONCLUSION

The study focused whether there is any significant difference in the academic achievement and self efficacy of higher secondary students with respect to their gender, locale and type of school. It was found that there exists significant difference in the academic achievement and self efficacy of higher secondary students with respect to their Gender. No significant difference was found in the academic achievement and self efficacy with respect to locality and type of school. Further it was found that there exists significant and positive relationship between academic achievement and self efficacy of higher secondary students.

Educational implications

Academic achievement is crucial as it directly influences students' positive outcomes and has consistently been used as a benchmark to assess learning achievements. It enables students to pursue opportunities in competitive fields. Therefore, it is very important to adopt such strategies which can boost high sense of self efficacy among the students as it influences students' beliefs in their abilities to succeed academically. Therefore, self-efficacy serves as a critical foundation for academic success by influencing motivation, goal setting, resilience. To boost self-efficacy and academic achievement of higher secondary school students, the following recommendations should be taken into consideration.

- Individualized guidance and support should be provided tailored to each student's strengths, weaknesses, and learning styles.
- Teachers should help students set specific, measurable, achievable, relevant, and time-bound (SMART) academic goals, fostering a sense of purpose and direction.
- Equip students with strategies to manage their time effectively, set priorities, and regulate their emotions and behavior to stay focused on their academic goals.
- Conducive environments should be cultivated where mistakes are viewed as opportunities for learning and growth, emphasizing the importance of effort and persistence in achieving success.
- There should be positive Teacher-Student Relationships, build trusting relationships with students based on mutual respect, encouragement, and support, creating a safe space for them to express themselves and seek assistance when needed.
- Teacher should Offer specific, timely, and constructive feedback on students' academic performance, highlighting their strengths and areas for improvement to enhance their self-efficacy and motivation.
- Enhance Peer Collaboration: Facilitate collaborative learning activities and group projects that promote peer interaction, communication, and collaboration, allowing students to learn from each other and develop social support networks.
- Effective study techniques such as time management, note-taking, active reading, and exam preparation strategies should be developed among the students. By implementing these strategies, educators can help higher secondary students develop the confidence, skills, and motivation needed to excel academically.

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REFERENCES

- Ahuja, A. (2016). Study of Self-Efficacy among Secondary School Students In relation to Educational Aspiration and Academic Achievement. *Educational Quest: An Int. J. of Education and Applied Social Sciences*, 7(3), 275-283.
- Bandura, A. (1994). Self-efficacy: towards a unifying theory of behavioral change. *Psychological review*, 84, 191-215.
- Bhati, K., Baral, R. & Meher, V. (2022). Academic Self-Efficacy and Academic Performance among Undergraduate Students in Relation to Gender and Streams of Education. *Indonesian Journal of Contemporary Education*, 4(2), 80-88. ISSN: 2656-033X.
- Hasan, M. and Parvez, M. (2019). Effect of Self-Efficacy, Gender and Locale on the Academic Achievement of Secondary School Students. *International Journal of Scientific Research and Reviews*, 8(2), 1881-1894.
- Mehmood, A., Adnan, M., Shahzad, A. & Shabbir, F. (2019). The Effect of Self-Efficacy on Academic Performance at Higher Level of Learning: A Case Study of Punjab University Lahore. *Journal of Educational Sciences & Research Spring*, 6(1), 33-47.
- Mir, A. H., Sivakumar, R. (2023). Academic Procrastination and self-efficacy among adolescent students. A correlational study. *The Online Journal of Distance Education and e-Learning*, 11(4), 3018-3023.
- Mimrot, B. H. (2016). A Study of Academic Achievement Relation to Home Environment of Secondary School Students. *The International Journal of Indian Psychology*, 4(1), 31-40. ISSN: 2348-5396
- Oyuga, P. A., & Raburu, P. A. (2019). Relationship between Self-efficacy and Academic Performance among Orphaned Secondary School Students in Kenya. *International Journal of Psychology and Behavioral Sciences*, 9(3): 39-46.
- Shkullaku, R. (2013). The Relationship between Self – efficacy and Academic Performance in The Context of Gender among Albanian Students. *European Academic Research*, 1(4), 467-478.
- Talluri, S. (2018). Self efficacy of secondary school students in relation to their gender and type of management. *International Journal of Research and Analytical Reviews*, 5(3), 1131- 1133. ISSN: 2349-5138.
- Ubhe, Y., & Bombra, P. (2017). Self-concept, self-efficacy and achievement motivation among the middle school and high school students," *International Journal of Research in Social Sciences*, 7(6), 334-348.

Significance of Difference between the mean score of academic achievement of higher secondary students with respect to their gender.

Table 1:

Variable	Gender	N	Mean	SD	t value	Level of significance
Academic Achievement	Male	391	56.62	11.33	2.84	Significant
	Female	349	59.00	12.34		

It is found from the table 1 that the calculated t value is 2.84 which is higher than the table value of 1.96 at 0.05 level of significance. Hence the above stated null hypotheses is rejected and it is concluded that male and female higher secondary students differ significantly in their academic achievement.

Significance of Difference between the mean score of academic achievement of higher secondary students with respect to their locality.

Table 2:

Variable	Locality	N	Mean	SD	t value	Level of significance
Academic Achievement	Rural	365	57.57	11.20	0.91	Not Significant
	Urban	375	58.63	11.24		

It is found from the table 2 that the calculated t value is 0.91 which is lesser than the table value of 1.96 at 0.05 level of significance. Hence the above stated null hypotheses is accepted and it is concluded that rural and urban higher secondary students do not differ significantly in their academic achievement.





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Significance of Difference between the mean score of academic achievement of higher secondary students with respect to their type of school.

Table 3:

Variable	Type of School	N	Mean	SD	t value	Level of significance
Academic Achievement	Government	367	57.06	11.35	0.35	Not Significant
	Private	373	58.55	11.22		

It is found from the table 3 that the calculated t value is 0.35 which is lesser than the table value of 1.96 at 0.05 level of significance. Hence the above stated null hypotheses is accepted and it is concluded that academic achievement of higher secondary students do not differ significantly with respect to their type of school.

Significance of Difference between the mean score of self-efficacy of higher secondary students with respect to their gender.

Table 4:

Variable	Gender	N	Mean	SD	t value	Level of significance
Self-efficacy	Male	391	79.68	16.35	2.45	Significant
	Female	349	81.39	14.24		

It is found from the table 4 that the calculated t value is 2.45 which is higher than the table value of 1.96 at 0.05 level of significance. Hence the above stated null hypotheses is rejected and it is concluded that self-efficacy of higher secondary students differ significantly with respect to their gender.

Significance of Difference between the mean score of self-efficacy of higher secondary students with respect to their locality.

Table 5:

Variable	Locality	N	Mean	SD	t value	Level of significance
Self-efficacy	Rural	365	81.62	16.49	0.81	Not Significant
	Urban	375	82.60	16.44		

It is found from the table 5 that the calculated t value is 0.81 which is lesser than the table value of 1.96 at 0.05 level of significance. Hence the above stated null hypotheses is accepted and it is concluded that self-efficacy of higher secondary students do not differ significantly with respect to their locality.

Significance of Difference between the mean score of self-efficacy of higher secondary students with respect to their type of school.

Table 6:

Variable	Type of school	N	Mean	SD	t value	Level of significance
Self-efficacy	Government	367	81.12	15.64	1.36	Not Significant
	Private	373	82.07	15.49		

It is found from the table 6 that the calculated t value is 1.36 which is lesser than the table value of 1.96 at 0.05 level of significance. Hence the above stated null hypotheses is accepted and it is concluded that self-efficacy of higher secondary students do not differ significantly with respect to their type of school.

Table 7: Coefficient of correlation between academic achievement and self-efficacy of higher secondary students

Variable	N	r value	Level of significance
Academic Achievement and Self-efficacy	740	0.496**	Significant

** Correlation at 0.01 level (2-tailed)

From the table 7, the obtained coefficient of correlation (r) between academic achievement and self-efficacy of higher secondary students is found to be 0.496 which is significant at 0.01 ($p < 0.01$). Hence the above stated null hypotheses is rejected and it is concluded that there is a significant and positive relationship between academic achievement and self-efficacy of higher secondary students.





Effect of Positional Release Technique in Improving Range of Motion and Pain Pressure Threshold in Patients with Myofascial Trigger Points in Upper Trapezius Muscle: A Systematic Review

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ABSTRACT

The study proposes to systematically analyze the effect of the positional release technique in patients with upper trapezius myofascial trigger points. Neck pain is an extremely ubiquitous and augmenting health problem. One of its paramount roots is trapezius trigger points. This is a very customary source of physical limitations and a deterioration in quality of life. For decades exclusive therapeutic strategy has been established to execute the myofascial trigger points (MTrPs) of the upper trapezius including the positional release technique (PRT). This review is designed to extort and enumerate literature promising the use of PRT in treating MTrPs of the upper trapezius muscle. Randomized clinical/controlled trials were searched systematically from 2013 to 2023 using the Cochrane Central Register of Controlled Trials, PubMed, Google Scholar, Pedro, and MEDLINE. Four main outcome parameters were evaluated: pain threshold, cervical range of motion, pain intensity, and neck disability. Two authors using the PEDro scale appraised the methodological quality independently. A risk-of-bias assessment was also conducted. After fulfilling the inclusion and exclusion criteria, 8 articles were assimilated in the systematic review; the quality of the studies was ambiguous. Two independent authors verified and screened data, third author double-checked and searched for additional articles. Findings reveal that PRT affects clinical presentation in patients with MTrPs of the upper trapezius by improving pain pressure threshold along with an escalating cervical range of motion, reducing pain intensity and occurrence of neck disability.





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INTRODUCTION

Myofascial pain syndrome (MPS) is a chronic musculoskeletal pain disorder characterized by muscle pain and discomfort along with stiffness, muscular fatigue, and subjective weakness.[1] Of all the patients reporting at a pain rehabilitation centre, MPS is one of the most common musculoskeletal pain syndromes that almost 85% of them experience once in a lifetime [2]. The overall prevalence rate of the reported patients with MPS varies with different patient populations and among both genders. However, an average of 80% of the general population is afflicted by MPS, out of which 10-20% can be classified as chronic [3]. Therefore there is no denial to consider that MPS has the potential to become one of the most significant clinical issues for the general population in the years to come. MPS can be defined as the development of myofascial trigger points (MTrPs) within any part of the body along with perceived deep aching pain that is localized as well as referred to a distant but defined region [4]. MTrPs are the hyperirritable points confined to the palpable taut bands within the skeletal muscles or the fascia around it that give rise to discomfort and referred pain upon compression along with other motor and autonomic dysfunctions. It can be broadly classified as either active or latent. The active MTrPs can be distinguished as the source of the presenting pain complaint and have other characteristics like tenderness, local twitch, and replicating spontaneous referred pain response on compression or stretch; taut band; stiffness; reduced joint range of motion (ROM); muscle weakness; paresthesia; and changes in body temperature. Whereas, latent MTrPs are ordinarily asymptomatic and may produce the symptoms in response to compression, tension, or overload of the affected tissues.[5] Although many of the skeletal muscles are susceptible to developing MTrPs, in clinical settings, the upper trapezius muscle is alleged to be affected most.[6] The exact cause precipitating the development of MTrPs in the upper trapezius is still not known, but factors like inappropriate head and neck posture along with abnormal movement patterns resulting in micro-injuries and ischemia that are further aggravated by the decreased supply of oxygen and nutrients to the muscles and other stresses being imposed on it might cause this.[7] Moreover, being a postural muscle the upper trapezius works continuously against gravity to maintain an upright head and neck position, thus making it highly suspected of being overused. This also could be another factor provoking the development of MTrPs in the upper trapezius.

Patients with upper trapezius MTrPs may feel knotted around the upper back, shoulder, or neck which when touched may give rise to severe pain and discomfort spreading beyond the surrounding location. It might also result in neck stiffness, limited cervical rotation and lateral flexion, elevated shoulders, neck discomfort, and headaches.[5] A variety of physiotherapeutic techniques exist for the management of upper trapezius MTrPs, of which one of the most used techniques is the positional release technique (PRT). It is a passive indirect technique that involves the positioning of the affected part in a comfortable position by moving it in all three planes of motion while being guided by the palpation of the tender points within the MTrPs to determine the adequate position first. PRT evokes physiological changes in the musculoskeletal system, normalizing hypertonicity and fascial tension by positioning the muscles in a way that optimizes relaxation. In addition, it raises circulation, reduces joint hypomobility, and subsequently reduces swelling and soreness while strengthening muscle [8,9] A considerable number of research papers on upper trapezius MTrPs have been published, examining the effects of PRT alone, in combination with other manual therapies, or with other conventional therapies. To our knowledge, hardly any recent study has summarized the impact of PRT on upper trapezius MTrPs. This systematic review therefore seeks to analyze the available data and provide an understanding of the PRT treatment approach for upper trapezius MTrPs on patients to provide applicable therapeutic recommendations, direct future research, and identify and deliver the best care for this debilitating condition.





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METHODS

Registration & Protocol

This systematic review was prospectively registered on the International Prospective Register of Systematic Reviews (PROSPERO) with registration number CRD42023453737. The findings are being reported in this systematic review as per the updated Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. [10] A formal review protocol was never prepared but the procedure to be undertaken was mentioned during the PROSPERO registration, thus can be assessed from there.

Information Sources

A comprehensive primary search of the scholarly literature databases including PubMed, Google Scholar, PEDro, MEDLINE, and Cochrane have been executed between June 2023 and September 2023. A secondary scan through the reference lists of the published review articles was also attempted to identify any additional studies potentially missed during the electronic search.

Search Strategy

The PICOS (Population, Intervention, Comparison, Outcomes, and Study) approach was used for the extensive search.[11] clinical/controlled trial studies (S) evaluating the effectiveness of PRT as an intervention (I) against other physiotherapeutic techniques, placebo, or no intervention at all in comparison (C) on pressure pain threshold (PPT) measured by pressure algometer and cervical ROM using universal goniometer as primary outcomes and pain intensity measured by visual analogue scale (VAS) or numeric pain rating scale (NPRS) and neck disability assessed by neck disability index (NDI) as secondary outcomes (O) in patients with upper trapezius MTrPs (P) were considered in this systematic review. The search was done between the period of October 2023 to November 2023. The search strategy included a considerable search of the electronic databases based on a combination of free-text words or keywords including the upper trapezius, cervical, neck pain, trigger point, positional release technique, pressure pain threshold, range of motion, and related MeSH (Medical Subject Headings) terms along with Boolean operators like AND, OR, and NOT using advanced search options.

Selection Criteria

Studies had to meet the inclusion criteria to be included in the review. Only available full-text randomized controlled/ clinical trials published between January 2013 to August 2023 considering participants diagnosed with upper trapezius active or latent MTrPs, using PRT as an intervention for its treatment, and concerned with the therapeutic effectiveness of the treatment were only included for the systematic review. Articles published in the English language were only contemplated without any geographical exclusion criteria. Studies with participants having neck pain due to some other cause or being treated with some other therapeutic exercises were not considered for the review. Nonrandomized trials, quasi-experiments, observational studies, case series, and case studies were excluded. Studies not available in the English language or full text were also excluded.

Selection Process

In the initial phase, the titles and abstracts from the searched articles were screened and evaluated independently by two impartial reviewers for the selection criteria. In the subsequent phase, the full texts of the selected articles were acquired and assessed for compliance with the eligibility criteria by the same reviewers. Cases of disagreement between the two reviewers regarding the inclusion of the studies were resolved by the third reviewer. All the reviewers verified the included studies and an overview of the decisions taken during the selection of the studies has been shown in the PRISMA flowchart (Figure 1).

Data Extraction

Data-extraction forms were used for information regarding the title, authors, country, year of publication, study design, sample size (for each group), interventions, outcome measures (categorized by pain, pain pressure threshold, range of motion, and neck disability), results, adverse events, conclusion, and funding sources. Data was assessed and extracted by authors independently from the full-text documents and were double-checked by the authors. In





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case of disagreement, a third author was consulted. The authors only included data from neck pain patients with MTrPs in the upper trapezius muscle who have undergone PRT with other conventional therapies.

Risk of Bias Assessment

Review manager 5.4.1 version used for assessing the risk of bias in randomized trials was used to evaluate the quality of each RCT. All the included RCTs were evaluated under its 6 domains of assessment including sequence generation, allocation concealment, blinding of participants, blinding of outcome assessors, incomplete outcome data, and selective outcome reporting. Each domain was then rated as either high, low, or unclear risk based on its score.

Data Synthesis

The initial validity of the selected articles was assessed using the physiotherapy evidence database (PEDro) for studies investigating the effectiveness of physiotherapy intervention [12]. In this review, PEDro investigated the effectiveness of PRT intervention in scrutinized articles. An 11-item measure was used to evaluate the reliability and methodological quality of the included randomized controlled/clinical trials in the present review.

RESULTS

The studies' search and selection procedures were conducted according to the PRISMA guideline, as mentioned in Figure 1. The search strategy identified 19,387 records from five databases and records from other sources (reference list of the published reviews and included studies). Following the removal of the duplicate articles, a total of 1123 articles were screened for titles and abstracts. Further excluding, 858 records for their titles and abstracts not meeting the inclusion criteria and thus gives a total of 265 potentially admissible records. Out of these 178 records could not be retrieved thus leaving 87 full-text records that were assessed for eligibility. Of these remaining records, 32 articles did not concern upper trapezius trigger points, 25 articles were published in a language other than English, 10 articles did not include any physiotherapy intervention, 6 articles were registered protocol type, and 6 articles were of different study design. So a total of 8 articles remained. The tables describe the organization and tabulation of the data extracted from these 8 articles based on the characteristics of the included studies in Table 1; objectives and primary outcomes in Table 2; and methodological quality analysis of the studies in Table 3.

Characteristics and Outcomes of the Included Studies

As mentioned, Table 1 depicts the characteristics of the included studies. All the included studies were published between 2013 and 2023. Sample sizes of the studies ranged between 30 to 60. Out of the eight studies included two were from India and Iran each, while the rest were from the USA, Egypt, Jordan, and Poland. Participants in each study were both males and females aged between 20 to 40 years. The PRT was considered an intervention in each study, either isolated or combined with conventional therapy or other physiotherapeutic interventions. To measure the effectiveness of PRT as an intervention to upper trapezius MTrPs in each study, the pain pressure threshold measured by a pressure algometer; cervical ROM measured by a universal goniometer, electro goniometer, or Myrin OB goniometer was; neck disability measured by the NDI; and pain intensity measured by the VAS or NPRS were used as outcomes.

Risk of Bias Within Studies

The risk of selection bias was minimal for both allocation concealment and random sequence generation. Likely the performance bias had the lowest risk of bias since the studies' blinding of the participants was disclosed. Because the authors of the studies failed to attain blinding of the assessor and also reported incomplete study protocols and important outcomes, they presented a high risk or uncertain danger for detection bias, attrition bias, and reporting bias. Other items also exhibited the highest risk of bias or unknown risk as can be seen in Figures. 2 and 3, which summarize the risk of bias. Two studies had a low risk of bias,[13,14] only one study had some concern of bias,[15] and five studies had a high risk of bias.[16-20]





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DISCUSSION

This review summarizes the use of PRT as an intervention related to the management of upper trapezius muscle MTrPs. A meta-analysis was not possible in the present review due to the heterogeneity of the included studies. MTrPs are the most evident condition in patients with neck pain. Various range of intervention procedures has been marked to positively influence the symptoms of neck pain and regaining health-related quality of life including manual techniques like myofascial release technique, manual pressure releases, manual stretching, muscle energy technique, deep transverse friction massage technique, and manual trigger points release, along with adjunct therapies like Kinesio-taping, dry needling and ice massage. The proposed intervention PRT is another addition to the list of manual therapies. Some literature refers to it as trigger point therapy or passive soft tissue therapy. Of all the eight studies included in the systematic review, most of them showed the superiority of the PRT as a stand-alone intervention for the treatment of MTrPs or in combination with other therapeutic techniques and a few demonstrated it inferior to other interventions.

Pressure Pain Threshold

The pressure algometer measuring pressure pain threshold was used as an outcome measure in six out of the included studies. It has been a reliable and valid tool for diagnosis as well as prognosis measurement of MTrPs. [21,22] Mohamed Ali OA et al. [13] a significant improvement in PPT following the treatment with PRT in comparison to ice massage as well as the control group being treated with conventional therapy and lifestyle modification. Such modifications were noticed for all three points on both sides. A similar result was noticed in the study by Kojidi MM et al.[19] when PRT was compared to sham treatment in the control group but failed to have a significant improvement against active soft tissue therapy both after three treatment sessions and follow-up at one week. Such improvements in both studies were postulated to be because of relaxation of the atypical reflexes with decreasing neural activation and stimulation of local mechanoreceptors by the movement of the muscle towards shortening. Contrary to these findings, in a study by Wendt M & Waszak M.[17] when combined with the muscle energy technique (MET), PRT showed significant improvement in PPT immediately after treatment and one day of follow-up in comparison to MET as well as PRT itself. Such an effect was proposed to be because of the stretching of the myofascial structures around the treated part induced by MET. However, the findings were different when the effectiveness of PRT was compared to manual therapies like therapeutic massage, manual passive muscle shortening, and manual pressure release. In contrast to therapeutic massage, PRT showed non-significant improvement in PPT but the improvement was consistent after two days of follow-up as demonstrated by Bethers AH et al. [15] Whereas, PRT was equivalently as effective as manual passive muscle shortening in improving PPT after three treatment sessions and ten days of follow-up in the study conducted by Amini A et al.[18] Shawabka SAM et al.[20] in their study found manual pressure release to be more effective as compared to PRT in improving PPT.

Range of Motion

Limitation in cervical ROM is the primary disability associated with the upper trapezius MTrPs and it can be measured using a universal goniometer, electro goniometer, or a gravity-reference goniometer. [23-25] Amongst the selected studies for review, six used cervical ROM as an outcome, of which the universal goniometer was used in four, and electro goniometer and gravity-reference goniometer were used in one study each. Incompatible with the conclusions concerning the PPT, the included studies reported that PRT as a treatment technique is less effective in increasing cervical ROM as compared to other treatments. This is evident from the findings of Shawabka SAM et al.[20] who reported a significant improvement in cervical contralateral side flexion in the manual pressure release group as compared to the PRT group. For the rest of the cervical motions, PRT was equally effective to that of manual pressure release. Similar results were also disclosed by Amini A et al.[18] and Kojidi MM et al. [19] suggesting no significant difference in cervical ROM between manual passive muscle shortening and active soft tissue therapy in comparison to PRT. Rathod S & Chaudhary K [14] on the other hand in their study described selective significant improvement in cervical extension, and rotation to both sides in the PRT group versus the Kinesio taping group after both the first as well as the second week of treatment. Mohamed ali OA et al. [13] in their study outlined a significant increase in all the cervical ROM following PRT as compared to the control group and Wendt M & Waszak M.[17]



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reported such results when PRT was used along with MET. These findings suggest that PRT is a less effective choice of treatment for increasing cervical flexibility and ROM in patients with upper trapezius MTrPs.

Pain Intensity

Increased pain intensity is a secondary factor disabling people with upper trapezius MTrPs. There are several methods to measure it, yet VAS and NPRS are the most commonly used measures. Five of the studies used VAS to measure pain intensity, whereas one of the studies used NPRS instead. Kojidi MM et al.[19] only concluded a significant decrease in pain intensity following treatment with PRT compared to active soft tissue therapy, while the rest suggested a non-significant improvement in favor of PRT.[12-15,17] This concludes that PRT is inferior to other therapeutic techniques in decreasing pain intensity in patients with upper trapezius MTrPs.

Neck Disability

NDI was used by two of the studies as an outcome to determine the associated neck disability. Rathod S & Chaudhary K [14] reported a significant decrease in NDI score in favor of PRT against Kinesio taping, whereas Patel N et al.[16] found no significant difference between the PRT group and the MET group following one week of treatment. Combined failure of PRT in improving cervical ROM and decreasing pain intensity explains the mixed result in terms of neck disability.

Strengths and Limitations

The extensive search carried out by the authors to identify potential articles related to the research question and adherence to best practice of methodological recommendations are the strengths of the present systematic review. To our knowledge, this is a unique systematic review enumerating studies focusing on the effectiveness of PRT as an intervention for managing upper trapezius MTrPs. There are some limitations in the present systematic review. To begin with, the low number of RCTs included affected the strength of the study. In addition, in most studies the authors have defined treatment in combination, therefore, making it difficult to target individual effects of the treatment protocol.

Implication on physiotherapy practice

The present review culminates that, PRT manual therapy in the upper trapezius is effective management. Key findings of the present review suggest that PRT can probably act as an important aspect in enhancing health-related quality of life among individuals, affected with MTrPs of the upper trapezius muscle by decreasing pain intensity and the associated tenderness. PRT techniques and exercise protocol in combination have the best results in the productive betterment of neck pain. Future research is required to identify and assess effective advanced therapies and better understand the individual rehabilitation needs of patients with upper trapezius trigger points.

Conflict of interest

All authors declare no conflict of interest.

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Abbreviations

MPS: Myofascial Pain Syndrome

MTrPs: Myofascial Trigger Points

PRT: Positional Release Technique

PROSPERO: International Prospective Register of Systematic Reviews



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PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses
PICOS: Population, Intervention, Comparison, Outcomes, and Study design
PPT: Pressure Pain Threshold
VAS: Visual Analog Scale
NPRS: Numeric Pain Rating Scale
NDI: Neck Disability Index
MeSH: Medical Subject Headings
MET: Muscle Energy Technique

REFERENCES

1. Staud R. Future perspectives: pathogenesis of chronic muscle pain. *Best Pract Res Clin Rheumatol.* 2007 Jun;21(3):581–96.
2. Fleckenstein J, Zaps D, Rüger LJ, Lehmeier L, Freiberg F, Lang PM, et al. Discrepancy between prevalence and perceived effectiveness of treatment methods in myofascial pain syndrome: Results of a cross-sectional, nationwide survey. *BMC MusculoskeletDisord.* 2010 Dec 11;11(1):32.
3. Bourgaize S, Newton G, Kumbhare D, Srbely J. A comparison of the clinical manifestation and pathophysiology of myofascial pain syndrome and fibromyalgia: implications for differential diagnosis and management. *J Can Chiropr Assoc.* 2018;62(1):27.
4. Saavedra FJ, Cordeiro MT, Vilaça Alves J, Fernandes HM, Reis VM, Mont'Alverni DGB. The influence of positional release therapy on the myofascial tension of the upper trapezius muscle. *Revista Brasileira de Cineantropometria e Desempenho Humano.* 2014 Jan 29;16(2).
5. Simons DavidG, Travell JanetG, Simons LoisS. *Travell & Simons' Myofascial Pain and Dysfunction: The Trigger Point Manual.* 2nd ed. Johnson E, editor. Vol. 1. Baltimore: Williams & Wilkins; 1999.
6. Sciotti VM, Mittak VL, DiMarco L, Ford LM, Plezbert J, Santipadri E, et al. Clinical precision of myofascial trigger point location in the trapezius muscle. *Pain.* 2001 Sep;93(3):259–66.
7. Fernández-de-las-Peñas C, Alonso-Blanco C, Fernández-Carnero J, Carlos Miangolarra-Page J. The immediate effect of ischemic compression technique and transverse friction massage on tenderness of active and latent myofascial trigger points: a pilot study. *J Bodyw Mov Ther.* 2006 Jan;10(1):3–9.
8. D'Ambrogio KJ, Roth GB. *Positional Release Therapy: Assessment & Treatment of Musculoskeletal Dysfunction.* St.Louis: Mosby; 1997.
9. Chaitow L. *Positional Release Techniques.* London: Churchill Livingstone; 2007.
10. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ [Internet].* 2021 Mar 29 [cited 2023 Nov 20];372. Available from: <https://pubmed.ncbi.nlm.nih.gov/33782057/>
11. Amir-Behghadami M, Janati A. Population, Intervention, Comparison, Outcomes and Study (PICOS) design as a framework to formulate eligibility criteria in systematic reviews. *Emergency Medicine Journal.* 2020 Jun;37(6):387–387.
12. de Morton NA. The PEDro scale is a valid measure of the methodological quality of clinical trials: a demographic study. *Australian Journal of Physiotherapy.* 2009;55(2):129–33.
13. Mohamed ali OA, Abdraoof NA, Ibrahim abdlhay M. Ice massage versus positional release on trapezius trigger points in nonspecific neck pain. *Eur Chem Bull.* 2023;12(5):4641–50.
14. Rathod S, Choudhary K. To Compare the Effectiveness of Positional Release Technique Versus Kinesio Taping in Patients with Upper Tapezius Trigger Points. *Indian J PhysiotherOccup Ther [Internet].* 2023 [cited 2023 Dec 3];17(1):94–9.
15. Bethers AH, Swanson DC, Sponbeck JK, Mitchell UH, Draper DO, Feland JB, et al. Positional release therapy and therapeutic massage reduce muscle trigger and tender points. *J Bodyw Mov Ther.* 2021 Oct 1;28:264–70.





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16. Patel N, Desai S, Patel P. Effectiveness of Muscle Energy Technique versus Positional Release Technique on Upper Trapezius Trigger Points in Subjects with Neck Pain – Comparative Study. *Int J Curr Res Rev.* 2021;13(11):87–91.
17. Wendt M, Waszak M. Evaluation of the Combination of Muscle Energy Technique and Trigger Point Therapy in Asymptomatic Individuals with a Latent Trigger Point. *Int J Environ Res Public Health.* 2020 Nov 14;17(22):8430.
18. Amini A, Goljaryan S, Kazem Shakouri S, Mohammadimajd E. The Effects of Manual Passive Muscle Shortening and Positional Release Therapy on Latent Myofascial Trigger Points of the Upper Trapezius: A Double-Blind Randomized Clinical Trial. *Iran Red Crescent Med J.* 2017;19(9):55579.
19. Kojidi MM, Okhovatian F, Rahimi A, Baghban AA, Azimi H. Comparison Between the Effects of Passive and Active Soft Tissue Therapies on Latent Trigger Points of Upper Trapezius Muscle in Women: Single-Blind, Randomized Clinical Trial. *J Chiropr Med.* 2016 Dec 1;15(4):235–42.
20. Al-Shawabka SAM, Shenouda S, Balbaa AA. Positional Release Technique Versus Manual Pressure Release on the Upper Trapezius Muscle in Patients with Myofascial Pain Dysfunction Syndrome. *Bull Fac Ph Th Cairo Univ.* 2013;18(1).
21. Reeves JL, Jaeger B, Graff-Radford SB. Reliability of the pressure algometer as a measure of myofascial trigger point sensitivity. *Pain.* 1986 Mar 1;24(3):313–21.
22. Ohrbach R, Gale EN. Pressure pain thresholds, clinical assessment, and differential diagnosis: reliability and validity in patients with myogenic pain. *Pain.* 1989 Nov 1;39(2):157–69.
23. Farooq MN, Mohseni Bandpei MA, Ali M, Khan GA. Reliability of the universal goniometer for assessing active cervical range of motion in asymptomatic healthy persons. *Pak J Med Sci [Internet].* 2016 [cited 2023 Dec 10];32(2):457. Available from: /pmc/articles/PMC4859044/
24. Law EYH, Chiu TTW. Measurement of Cervical Range of Motion (CROM) by electronic CROM goniometer: A test of reliability and validity. *J Back Musculoskeletal Rehabil.* 2013 Jan 1;26(2):141–8.
25. Balogun JA, Abereje OK, Olaogun MO, Obajuluwa VA. Inter- and Intratester Reliability of Measuring Neck Motions with Tape Measure and Myrin® Gravity—Reference Goniometer. <https://doi.org/10.2519/jospt.1989.10.7.248> [Internet]. 1989 Jan 1 [cited 2023 Dec 10];10(7):248–53.

Table 1. Demographic characteristics of articles addressing techniques used in the management of MTRPs of the upper trapezius muscle

Author	Year	Country	Research outline	Total participants	Age (year)* Mean ± SD
Mohamed Ali OA et al. ¹²	2023	Egypt	Randomized controlled trial	51	IM: 27.05 ± 2.30 PRT: 28.05 ± 3.64 CG: 26.29 ± 3.60
Rathod S et al. ¹³	2023	India	Randomized clinical trial	30	Not mentioned
Bether AH et al. ¹⁴	2021	USA	Randomized clinical trial	60	27.1 ± 8.8
Patel N et al. ¹⁵	2021	India	Randomized clinical trial	30	PRT: 34.66 MET: 37.66
Wendt M et al. ¹⁶	2020	Poland	Randomized clinical trial	60	Not mentioned
Amini A et al. ¹⁷	2017	Iran	Double-blind randomized controlled trial,	47	EG: 21.67 ± 1.49 CG: 21.07 ± 1.28
Kojidi MM et al. ¹⁸	2016	Iran	Single-blind, randomized clinical trial	42	PSTT: 27.86 ± 6.64 ASTT: 28.07 ± 5.94 CG: 28.29 ± 6.58
Shawabka SAM et al. ¹⁹	2013	Africa	Randomized clinical trial	45	MPR: 23 ± 3.40 PRT: 22 ± 1.80 CG: 21 ± 1.28

IM: Ice Massage; PRT: Positional Release Technique; CG: Control Group; MET: Muscle Energy Technique; EG:





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Experimental Group; PSTT: Passive Soft Tissue Therapy; ASTT: Active Soft Tissue Therapy; MPR: Manual Pressure Release;

Table 2. Presentation of articles according to the objectives and main findings regarding techniques used in the management of MTrPs of upper trapezius

Authors (year)	Objective	Intervention	Outcome measures	Results	Conclusion
Mohamed ali OA et al. (2023) ¹²	To compare the effectiveness of IM versus PRT on trapezius trigger points in non-specific neck pain.	Group A: IM + CT Group B: PRT + CT Group C: only CT	<ul style="list-style-type: none"> • Bournemouth questionnaire • VAS • PA • UG 	Significant improvement in all symptoms was noted in the PRT group compared to other groups.	6-month PRT in combination with conventional therapy can be an effective approach for managing trapezius trigger points related to non-specific neck pain.
Rathod S et al. (2023) ¹³	To examine the impact of PRT and KT in upper trapezius trigger points.	Group A: PRT+ CT Group B: KT+ CT	<ul style="list-style-type: none"> • UG • NPRS • NDI 	The PRT group showed relatively better significant improvement as compared to the KT group.	PRT combined with standard physiotherapy is more effective in reducing upper trapezius trigger points.
Bether AH et al. (2021) ¹⁴	To find out if PRT or TM is effective in treating upper trapezius trigger and tender points.	Group A: PRT Group B: TM	<ul style="list-style-type: none"> • VAS • PA • Ultrasound • Shear-wave elastography 	Both the groups showed significant improvement in the symptoms with the PRT group showing better results as compared to the TM group.	PRT is clinically more effective as compared to TM but none of them produce long-lasting effects on muscle stiffness.
Patel N et al. (2021) ¹⁵	To compare the effect of MET versus PRT on upper trapezius trigger points in patients with neck pain.	Group A: PRT + CT Group B: MET + CT	<ul style="list-style-type: none"> • VAS • NDI 	Both groups showed significant improvements in symptoms but when compared none was superior.	Both MET and PRT are equally effective in treating upper trapezius trigger points in patients with neck pain.
Wendt M et al. (2020) ¹⁶	To evaluate the influence of combined MET and TPT on asymptomatic patients with latent upper trapezius trigger points.	Group A: MET+TPT Group B: MET Group C: TPT	<ul style="list-style-type: none"> • Tensometric electrogoniometer • PA 	The MET+TPT group showed the most significant improvement in all the outcomes.	MET in combination with TPT can be a more effective approach for managing MTrPs of the upper trapezius.





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Amini A et al. (2017) ¹⁷	To assess the effect of MPMS versus PRT on the upper trapezius latent trigger points.	Group A: MPMS Group B: PRT	<ul style="list-style-type: none"> • VAS • PA • UG 	Statistically significant improvement in all the outcomes was seen in the MPMS group as compared to the PRT group.	MPMS therapy is more beneficial as a treatment option than PRT in latent triggers of the trapezius muscle.
Kojidi MM et al. (2016) ¹⁸	To analyze the influence of passive and active soft tissue therapies on upper trapezius muscle latent trigger points in women.	Group A: PSTT Group B: ASTT Group C: Sham group	<ul style="list-style-type: none"> • VAS • PA • UG 	The PSTT group showed a significant decrease in pain intensity compared to other groups but none superior in increasing contralateral cervical lateral flexion.	Both PSTT and ASTT can be treatment options to reduce pain and improve pain pressure threshold in patients with upper trapezius latent trigger points.
Shawabka SAM et al. (2013) ¹⁹	To compare the impact of PRT and MPR in patients with trigger points of upper Trapezius muscle.	Group A: PRT Group B: MPR	<ul style="list-style-type: none"> • PA • Myrin-OB Goniometer 	Significant changes in favour of the MPR group were discovered for related outcome measures.	In patients with trigger points of the upper trapezius, MPR showed significant improvement in pain and ROM as compared to PRT.
<p>IM: Ice Massage; PRT: Positional Release Technique; CG: Control Group; MET: Muscle Energy Technique; EG: Experimental Group; PSTT: Passive Soft Tissue Therapy; ASTT: Active Soft Tissue Therapy; MPR: Manual Pressure Release; UG: Universal Goniometer; PA: Pressure Algometer; VAS: Visual Analog Scale; NDI: Neck Disability Index; NPRS: Numeric Pain Rating Scale</p>					

Table 3. Methodological quality assessment of included studies via PEDro Scale

Authors (year)	Criterion											Score
	1	2	3	4	5	6	7	8	9	10	11	
Mohammad ali OA et.al (2023)	Y	Y	Y	Y	-	-	-	Y	-	Y	Y	6/10
Rathod S et.al (2023)	Y	Y	Y	Y	-	-	-	Y	-	Y	Y	6/10
Bether AH et.al (2021)	Y	Y	-	Y	-	-	-	Y	-	Y	Y	5/10
Patel N et.al (2021)	Y	-	-	Y	-	-	-	Y	-	Y	Y	4/10
Wendt M et.al (2020)	Y	-	-	Y	-	-	Y	Y	-	Y	Y	5/10
Amini A et.al (2017)	Y	Y	-	Y	Y	-	Y	Y	-	Y	Y	7/10
Kojidi MM et.al (2016)	Y	Y	-	Y	Y	-	-	Y	Y	Y	Y	7/10
Shawabka SAM et al. (2013)	Y	Y	-	Y	-	-	-	Y	-	Y	Y	5/10

*Y: yes

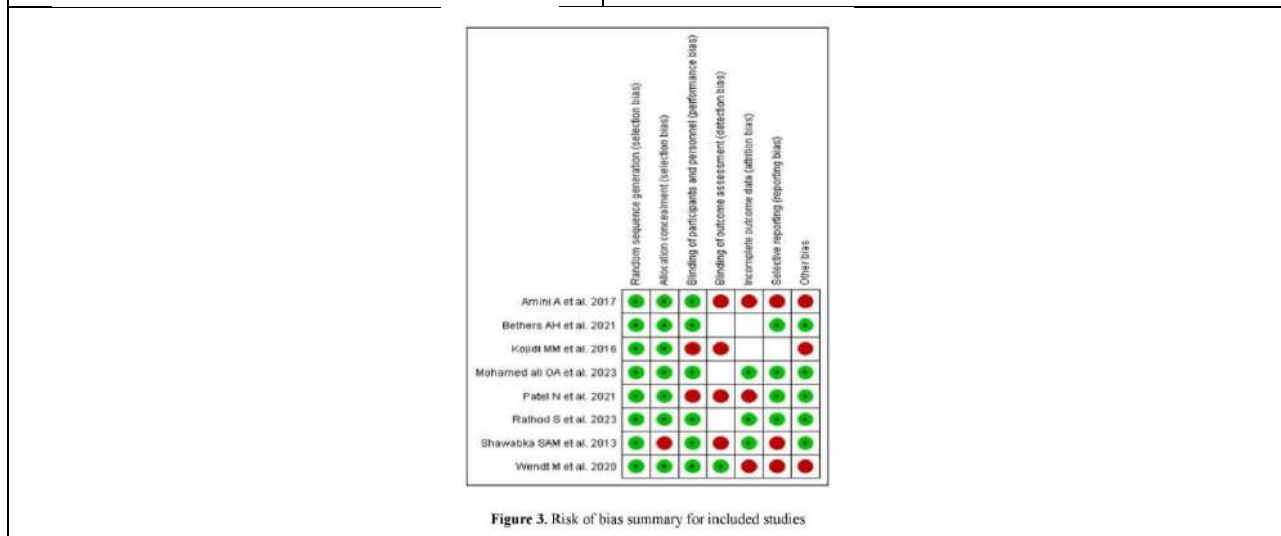
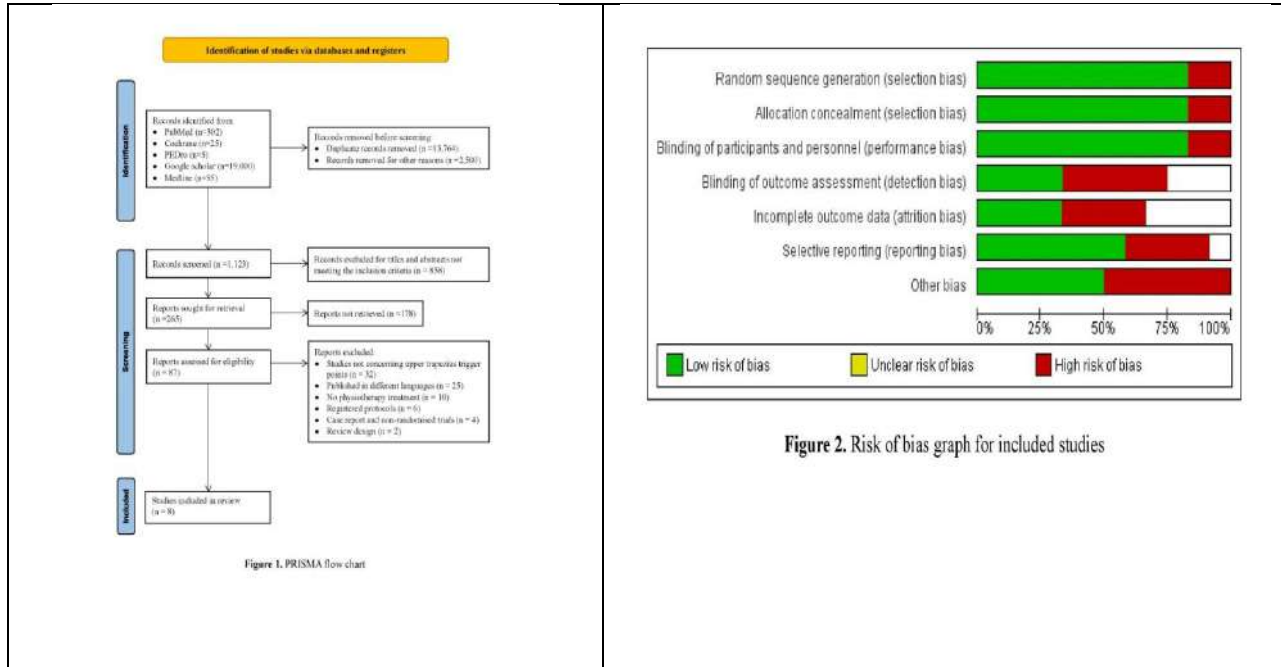
The study provides measures of variability. Each positive point in studies is given a score of 1 on 0 to 10. 1: Eligibility criteria were specified, 2: Subjects were randomly allocated to groups, 3: Allocation was concealed, 4: The groups were similar at baseline regarding the most important prognostic indicators, 5: There was blinding of all subjects, 6: There was blinding of all therapists who administered the therapy, 7: There was blinding of all assessors who measured at least one key outcome, 8: Measures of at least one key outcome were obtained from more than 85% of





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the subjects initially allocated to groups, 9: Intention to treat analysis, 10: Comparison between groups, 11: point measures and measures of variability.



Additional File: Prisma Checklist

Section and Topic	Item #	Checklist item	Location where item is reported
TITLE			
Title	1	Identify the report as a systematic review.	Page 4
ABSTRACT			





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Section and Topic	Item #	Checklist item	Location where item is reported
Abstract	2	See the PRISMA 2020 for Abstracts checklist.	Page 4
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	Page 5-6
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	Page 6
METHODS			
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	Page 7
Information sources	6	Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	Page 7
Search strategy	7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	Page 7
Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.	Page 8
Data collection process	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process.	Page 8
Data items	10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect.	Page 7
	10b	List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	Page 7
Study risk of bias assessment	11	Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.	Page 8-9
Effect measures	12	Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results.	No
Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis (e.g. tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5)).	Page 8
	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions.	No
	13c	Describe any methods used to tabulate or visually display results of individual	No





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Section and Topic	Item #	Checklist item	Location where item is reported
		studies and syntheses.	
	13d	Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	No
	13e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression).	No
	13f	Describe any sensitivity analyses conducted to assess robustness of the synthesized results.	No
Reporting bias assessment	14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	No
Certainty assessment	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	No
RESULTS			
Study selection	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.	Figure 1
	16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	No
Study characteristics	17	Cite each included study and present its characteristics.	Page 9
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	Figure 2,3
Results of individual studies	19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g. confidence/credible interval), ideally using structured tables or plots.	Page 11-12
Results of syntheses	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	Page 10
	20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	No
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	No
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	No
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	No
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	No
DISCUSSION			





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Section and Topic	Item #	Checklist item	Location where item is reported
Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	Page 10
	23b	Discuss any limitations of the evidence included in the review.	Page 12
	23c	Discuss any limitations of the review processes used.	No
	23d	Discuss implications of the results for practice, policy, and future research.	Page 13
OTHER INFORMATION			
Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	Page 6
	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	Page 6
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	No
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	Page 13
Competing interests	26	Declare any competing interests of review authors.	Page 13
Availability of data, code and other materials	27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review.	No





Studies on the Impact of Heavy Metal Chromium on Biochemical Changes in the Adult Male Insect *Sphaerodema rusticum* Relation to Reproduction (Heteroptera : Belostomatidae)

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ABSTRACT

The effects of medium lethal concentration of heavy metal chromium(14.20 ppm for 48h) exhibited a significant decline in the contents of glucose and glycogen in the fat body, haemolymph, testis and seminal vesicle. The toxicity impact of chromium on *Sphaerodema rusticum* was appropriate to be comparatively higher than any other insects. Since it has its own tolerance limit beyond 48h(14.20ppm)concentration in the aquatic environment. This intimate the non-target organism like *Sphaerodema rusticum* could be used as an effective indicator to assess the extent of chromium pollution in the aquatic environment.

Keywords: *Sphaerodema ruasticum*, haemolymph, fat body, testis, and seminal vesicle.

INTRODUCTION

Carbohydrate supplies major portion of energy to that living system. The male accessory reproductive gland (MARGs) of insects has been the subject of numerous investigations in relation to its specific roles in reproduction (Chen, 1971 and Selvi Sabhanayakam, 1995). The biochemical parameters are valuable in assessing and predicting the toxicological effect on the insects (Preethi sharma, 2011). The MARGs OF insects, the secretions they produce and the function they perform have been extensively studied in diverse groups of insects. The glands and the



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secretions they produce are known to be associated with such as oviposition, stimulation of spermatophore formation and even as contribution to yolk formation in females. Ambiga Shamugam (1977) and Ramakrishnan *et al.*, (1980) have described that in addition to yield of energy, glucose may be converted into glycogen, fat and amino acids. In insects, glycogen is the chief reserve carbohydrate as in other animals (Howder and kidly, 1961) and formed primarily from glucose and serve as reserve energy. This has been reported for *pocilicerus pictus* exposed to endosulfan (Prakash *et al.*, 1990) *Mylabris pustulata* exposed to chromium (Shanmugavelu, 1963); *Periplaneta* exposed to *pongamia glabra* leaf extract (Ramanathan, 1995); *Laccotrephes ruber* exposed to monocrotophos (Ravichadran 1996); Mercury chloride (Sivanandan, 2017). Carbohydrate along with Protein and lipid from the principal of classes organic compound that are found in insects. They contribute to the structure and function of all insect tissues. They occur in the nuclei, cytoplasm and plasma membrane at cellular level and also in the extracellular haemolymph and supporting tissues. In other words, carbohydrates are involved at all levels of cellular organization. Changes in the metabolic rate among organisms exposed to pollution stress have been used as indicators of stress conditions. Carbohydrate supply a major portion of energy to the living system (Ambigashanmugam, 1977) and Ramakrishnan *et al.*, (1980) have described that in addition to yield of energy, glucose may be converted into glycogen, fat and amino acid. Fat body, the principle tissue for intermediary metabolism in insects, is the main source for the protein, lipid and carbohydrates that serves as precursors for metabolism in other tissues (keeley, 1985) Sharma and Etheshamuddis (1992) on *Sphaerodema rusticum*, contribute to our standing of the importance of carbohydrate an energy source. Some heavy metals are essential, such as cadmium (Cd), nickel (Ni), arsenic (As), chromium (Cr), and Lead (Pb) are increasing to a dangerous levels for humans, plants and animals. Sharma and Agarwal (2005).

Intermediary metabolism includes multiple pathways in insects and the energy is stored as carbohydrates, lipid and proteins for energy production through degradation or synthesis (Nation, 2008). To understand the action of toxicants, several works have been undertaken on carbohydrate metabolism in insects. Thus effects of mercury chloride on *Sphaerodema rusticum* (Rajathi, 2004), nimbeciline on *Sphaerodema rusticum* (shoba, 2014), bioneem on *Laccotrephes ruber* (Babitha, 2017) have been analysed in relation to carbohydrate metabolism. From the forgoing literature, it is evident that the impact of chromium on carbohydrate content in the insect is meagre. It is clear from the present result that the presence of such heavy metals in the environment has an intense impact on *H. armigera* as far as food consumption and biochemical indices are concerned Adel Baghban (2014). Considering to results of the present study and others concerning metal accumulation in streams, the use of aquatic insects as bioindicators could be an important complementary strategy to detect metal pollution in aquatic environments in a more realistic way Renata, (2019). Therefore, it has been programmed in the present study to find out the impact of heavy metal, chromium on the glucose and glycogen contents in the adult insect, *Sphaerodema rusticum*.

MATERIALS AND METHODS

Adult insects were collected from rearing troughs and vivisected in insect Ringer solution (Emphrusi and Beadle, 1936). The colorimetric micro method of Kemp and Kits Van Heijninger (1954) was employed for the quantitative estimation of glucose and glycogen in fat body, haemolymph and testis and seminal vesicle. T-values are calculated to use the Statistical software SPSS.

RESULT

The glucose content of fat body, haemolymph, Testis and Seminal vesicle were increased in the treated insects than the control insects of about 1.97 ± 0.42 to 3.915 ± 0.32 , 55.62 ± 0.63 to 105.06 ± 0.68 , 3.25 ± 0.51 to 5.503 ± 0.36 , 43.34 ± 0.61 to $49.86 \pm 0.71 \mu\text{g}/\text{mg}$ respectively. The mean glucose content of haemolymph, fat body, testis and seminal vesicle control and treated insects were compared for significance of difference. For this purpose, the t-value was calculated and given in the Table 1. It was clear from the Table 1. The t-values of Fat body (4.540), haemolymph (234.773) Testis (11.401) and seminal vesicle (7.123) were significant at 0.01 level. Therefore, it may be concluded that the glucose





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content of the haemolymph, fat body, testis and seminal vesicle differed significantly in control and treated insects. The glycogen content of the haemolymph, fat body, testis and seminal vesicle were decreased in Chromium treated insects than the control insects about 7.20 ± 0.43 to 5.25 ± 0.58 , 6.48 ± 0.32 to 4.10 ± 0.48 , 4.62 ± 0.63 to 2.39 ± 0.62 , and 2.39 ± 0.18 to 1.44 ± 0.30 $\mu\text{g}/\text{mg}$, respectively. The mean glycogen and content of the fat body, haemolymph, testis and seminal vesicle in the control and treated insects were compared for significance of difference. For The t-values of Fat body (5.157), haemolymph (10.942), testis (9.851), and seminal vesicle(5.410) were significant at 0.01 level. Therefore, it may be concluded that the glycogen content of the fat body, haemolymph, Testis and Seminal vesicle significantly differed in control and treated insects.

±Data represent mean values of six observation; **Denotes significant at 0.01 level.

There is significant difference between the control and treated insect tissues and haemolymph glucose content.

±Data represent mean values of six observation; **Denotes significant at 0.01 level.

There is significant difference between the control and treated insect tissues and hemolymph glycogen content.

DISCUSSION

There is significant difference between the control and treated insect tissues and haemolymph glucose content. In the present study, it has been observed that the amount of glucose and glycogen were found to be increased and decreased respectively, when *Sphaerodema rusticum* intoxicated with the medium lethal concentration of chromium than control insects. This work is in parallel with the works of (Rajathi *et al.*, 2003) who have reported for *s.rusticum* when exposed found in fat body, haemolymph, testis and seminal vesicle due to treatment with chromium. Glycogen is an important nutrient reserve in animal tissue and it is used as an immediate energy source when required by any animals. Therefore, glycogen is an essential component of the normal metabolism (Thunberg and Manchester, 1972). The increased glucose and glycogen level were found in the fat body and haemolymph of *Laccotrephes ruber* due to the toxic effect of bioneem (Babitha, 2017). Similar findings have been reported by (Shanmugam, 2017) on *Sphaerodema rusticum* when treated with cadmium. *Laccotrephes ruber* when treated with monocrotophos (Ravichandran, 1996), *Gryllotalpa Africana* when treated with endosulfan (sumathi, 2001), *Laccotrephes ruber* when treated with zinc (Ramash Kumar, 2004), The present study has revealed that the occurrence of higher quantity of glucose in the haemolymph of the insect after treatment and this may due to transportation of glucose from the storage organ namely, the fat body . Thus the bio-chemical variations in the quantity of glucose and glycogen in the haemolymph, fat body, testis and seminal vesicle of the adult insect *Sphaerodema rusticum* seems to be due to treatment with the heavy metal chromium.

REFERENCES

1. Adel Baghban, Jalal Jalali Sendi, Arash Zibae, Roya Khosravi .2014 Effect of heavy metals (Cd, Cu and Zn) on feeding indices and energy reserves of the cooten boll worm *Helicoverpa armigera* Hubner (Lepidoptera:Noctuidae). Journal of plant production research, Vol, 54, No.4 (2014).
2. Ambiga, Shanmu gam.1997. Fundamentals of Biochemistry for medical student, Madras.
3. Babitha B. 2017. Studies on impact of phytopesticide Bioneem on the biochemical changes in reproductive tissues on *Laccotrophes ruber* in relation to reproduction M. Phil. Thesis., Thiruvalluvar University.
4. Emphrussi, B. and Beadle, G.N. 1936. A technique of transplantaion for *Drosophila*. *Amer. Nat.* 70:218-225.
5. Keeley, L.L.1985. Physiology and biochemistry of fat body. In: Comprehensive Insect Physiology, Biochemistry and Pharmacology Vol I. Embryogenic and Reproduction. Pragamon Press, Oxford. 211-242.
6. Nation J.L. 2008. Insect physiology and Biochemistry. 2nd ed. CRC Press, New, USA, 544pp.
7. Preethi Sharma, Lalit Mohan, Kamal Kumar Dua, Chand Narayan Srivastaava*, 2011. Status of carbohydrate, protein and profile in the mosquito larvae treated with certain phytoextracts. Asian Parafic Journal of Tropical Medicine (2011)301-304.





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8. Rajathi,V. 2003.Impact of heavy metal mercury on biochemical changes in the adult insect *Sphaerodema rusticum* in relation to excretion. *In.J. Env. And Ecoplan* 7(1) 25-28.
9. Ramakrishnan,S. 1980. Text book of Medical biochemistry. Orient Longman, Madras. PP.235-265.
10. Rameshkumar, T. 2004. Studies on impact of heavy metal zinc on certain selected tissues in the adult male *Laccotrophes ruber*(Linn.) (Heteroptera:Nepidae) in relation reproduction. Ph.D. Thesis, Annamalai University.
11. Renata de Moura Guimaraes Souto, Juliano J. Corbi and Giuliano Buza Jacobucci, 2019. Aquatic insects as bioindicators of heavy metals in sediments in cerrado streams. *Limnetica*, 38 (2): 575-586 (2019).
12. Shanmugam, S.2017.Impact of heavy metal cadmium on biochemical and histopathological changes in *Sphaerodema rusticum* in relation to excretion. *M. Phil. Thesis.*, Thiruvalluvar University.
13. Sharma R.K., Agarwal M. 2005. Biological effects of heavy metals: an overview. *J. Environ. Biol.* 26 (Suppl. 2): 301-313.
14. Shoba,V. 2014.Effect of phytopesticide Nimbecidine on the Biochemical parameters of the reproductive tissues of *Sphaerodema rusticum*.*In. J. Pharma. Research Scholars.* V-3,1-2,2014
15. Sivanandan, M. 2017. Studies on impact of heavy metal lead Chloride in the adult male reproductive physiology of *Sphaerodema rusticum* M.Phil. Thesis., Thiruvalluvar University.
16. Sumathi, S., 2001. Studies on impact of Endosulfan on certain selected tissues of the adult male insect *Gryllotalpa africana* (Palisot der Beauvois) (Orthoptera: Gryllotalpidae) in relation to reproduction. Ph.D., Thesis, Annamalai University.

Table 1. Glucose content of Fat body, Haemolymph, Testis, and Seminal vesicle of control and Chromium treated adult male insect, *s.rusticum* (Quantity expressed in $\mu\text{g}/\text{mg}$ wet wt. in case of tissues and $\mu\text{g}/100\text{ul}$ in case of Haemolymph).

Tissue	Control ($\mu\text{g}/\text{mg}$)	Treated ($\mu\text{g}/\text{mg}$)	Percent change over control	T- values
Fatbody	1.97 \pm 0.42,	3.915 \pm 0.32	98.73	4.540*
Haemolymph	55.62 \pm 0.63	105.06 \pm 0.68	88.88	234.773*
Testis	3.25 \pm 0.51	5.503 \pm 0.36	63.32	11.401*
Seminal vesicle	43.34 \pm 0.61	49.86 \pm 0.71	15.04	7.123*

Table2. Glycogen content of fat body, Heamolymph, Testis, and Seminal vesicle of control and Chromium treated adult insect, *s.rusticum* (Quantity expressed in $\mu\text{g}/\text{mg}$ wet wt. in case of tissues and $\mu\text{g}/100\text{ul}$ in case of Haemolymph).

Tissue	Control ($\mu\text{g}/\text{mg}$)	Treated ($\mu\text{g}/\text{mg}$)	Percent change over control	T- values
Fat body	7.20 \pm 0.43	5.25 \pm 0.58	-27.08	5.157*
Haemolymph	6.48 \pm 0.32	4.10 \pm 0.48	-36.72	10.942*
Testis	4.62 \pm 0.63	2.39 \pm 0.62	-48.26	9.851*
Seminal vesicle	2.39 \pm 0.18	1.44 \pm 0.30	-39.74	5.410*





Nutritional and Health Benefits of Foxtail Millet: A Review

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ABSTRACT

Foxtail millet (*Setaria italica* L.) is commonly known as Kangni in Hindi. It is considered a functional food due to its health-promoting properties with nutritional benefits. Foxtail millet contains a rich amount of macro-nutrients like energy, proteins, essential fatty acids and micro-nutrients like vitamins and minerals such as Ca, Fe, Mg, K and Zn and bioactive compounds such as antioxidants, total flavonoid, dietary fiber, which helps to prevent lifestyle disorder like obesity, cardiovascular, hypertension, and diabetes, it is non-acid forming food which is easy to digest and good for gastrointestinal health also gluten-free which help to prevent celiac disease. Developed value-added foxtail millet-based food like cookies, papad, chocolate, muffin, bread, rusk, kheer, pinni, sattu, vegetable dalia, bar and chips enhance our fight against malnutrition in children and adolescents and also help to foster immunity and wellness. The utilization of foxtail millet in a mixture with other cereals, millet, pseudocereals and legumes for healthy food alternatives has become an emerging area for the food industry. The nutritional potential of foxtail millet plays a significant role in the world's nutritional security as well as functional benefits may also help to prevent metabolic disorders which is evidence-based and will be described in this paper.

Keywords: Nutritional potential, Phytochemical, gluten-free, lifestyle disorder

INTRODUCTION

Millet is generally found in round-shaped grain seeds, that vary in color and size depending on the based on their type. Millets like sorghum and maize are Poaceae plant family members (Sharma & Niranjana 2018). Pearl millet (*Pennisetum glaucum*), is the most abundant, consuming over 40% of global output across all manufacturing regions, and is a result of foxtail millet, proso millet, and finger millet. The millet family includes kodo millet, little millet, and



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barnyard millet (*veranda et al., 2021*). Foxtail millet has been known as a minor millet and ranked as the 6th highest-yielding grain in terms of global production. In India, it is widely called Kangni, Kang, Navane, koan Dana, Kavalai, Tenai, and Kangam (*Bhavya et al., 2020*). Foxtail millet is grown in 26 countries and is the world's second-largest millet producer. When compared to other millets, it can grow 2-5 feet tall and farmed in hot and colder climates. It can grow in sandy and loamy soils. It is commercially significant in the semi-arid tropics and harvested 75-90 days after planting. Millets are the richest source of vitamins and minerals including Fe, Ca, K, Zn, and Mg. and crude edible fiber (*Maitra et al., 2020*). Millets provide several health advantages due to their low glycemic index and load, as well as their gluten-free composition. It displays anticancer, antioxidant, anti-cholesteric, and anti-hypertensive qualities that aid in the treatment of specific diseases including cancer, gastrointestinal disorder, atherosclerosis, obesity, and celiac disease (*Mounika et al., 2022*).

GEOGRAPHICAL DISTRIBUTION

Foxtail millet is an ancient minor millet that has made a significant contribution to human civilization in both Asia and Europe (*Kuo et al., 2018*). It was domesticated in China 8,700 years ago, according to the most recent archaeological findings, making it one of the oldest crops. The main production region includes China, India, Afghanistan, Central Asia, Korea, and Georgia. Foxtail millet has gradually declined in importance over the past 80 years due to the rapid growth of maize and other contemporary crops, but it is still commonly grown as a grain food or forage across Asia, Europe, North America, Australia and North Africa. In India, foxtail millet is primarily grown in Andhra Pradesh, Karnataka, Uttar Pradesh and Tamil Nadu (*Sagar et al., 2020*).

NUTRITIONAL COMPOSITION OF FOXTAIL MILLET

Millets are unique because of their richness in polyphenols protein, dietary fibre and calcium. Foxtail millet is gluten-free, non-acidic farming, and easily digestible. It is also high in macro-nutrients, fatty acids, vitamins, minerals and soluble fiber. Its protein is high in essential amino acids and high in sulfur-containing amino acids like methionine and cysteine. It is rich sources in phytochemicals, micro-nutrients, and antioxidants such as phenolic acids and glycosylated flavonoids (*Devisetti et al., 2014*). It has a lower glycemic index value which has been attributed to improved glucose metabolism. Millet has anti-oxidative properties against oxidative stress. (*Rathore et al., 2016*).

PHYTOCHEMICAL COMPOSITION OF FOXTAIL MILLET

Phytochemical

Phenolic is the most important antioxidant found in foxtail millet. They act chemically by donating H-atoms to electron-deficient free radicals via benzene rings' hydroxyl groups, resulting in the formation of a resonance-stabilized and low-reactive phenoxyl radical. Foxtail millet and other millets have also been shown to be effective as reducing agents, singlet O₂ quenchers, and metal chelators (*Nitya & Keshavan, 2017*).

Phenolics and Flavonoids

The aromatic secondary metabolites of plants called phenolic compounds are responsible for the color of food (gray, yellow, green and creamy white), as well as its sensory and nutritional aspects and antioxidant capabilities. They are generally available in plants and millets. These are part of everyday diet. Phenolic compounds are phenolic acids, flavonoids, tannins, and saponins. Phenolic-rich foods act as an antioxidant and healthful medicine due to their health benefits due to the presence of substances like flavonoids and phenolic acid in *them* (*Jha et al., 2013*). some phytochemicals are described with their molecular weight in this table :

Tannin

Tannins are the class of 500 Da molecular weight polyphenols that are found in plants. The carbon and hydroxyl groups of tannin are known to form complexes with protein. Tannin affects protein digestion and prevents the body from utilizing important amino acids and minerals. There are two different types of naturally occurring groups hydrolysable made up of gallotannin and ellagittannins and condensed consisting of proanthocyanidin.





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It affects iron absorption and negatively impacts iron stores, leading to the reduction of essential amino acids by forming tannin protein complexes, and inhibiting enzymes like pepsin, trypsin etc. It is found in food sources like tea, cocoa, berries, apples, whole grains, beans, nuts, pulses and legumes. It can be reduced by boiling, steaming, soaking, roasting and germinating (*Sharma et al., 2015*).

PHARMACOLOGICAL ROLE OF FOXTAIL MILLET

DIABETES

Diabetes mellitus causes severe alteration in the plasma lipid and lipoprotein profile, and increases the risk of early atherosclerosis, coronary insufficiency and myocardial infarction (*Anitha et al., 2022*). It also promotes lipid accretion as a result of insulin insufficiency, making patients more susceptible to both high blood glucose and high cholesterol (*Dias et al., 2018*). Several epidemiological studies have found that including foxtail millet in one's regular diet reduces the chance of acquiring degenerative illnesses, such as cholesterol metabolism and type 2 DM. Because of their capacity to inhibit clinical and hydroxyl radicals, bioactive chemicals found in foxtail millet have anti-diabetic properties (*Srinivasan et al., 2009*). The range of vitamins, minerals, phytochemicals, and other bioactive compounds in foxtail millet contribute to its health advantage, making it a potential functional food. According to a study people who consume millet had a decreased risk of developing diabetes. Millet phenolic, like alpha-glucosidase, prevents postprandial hyperglycemia by inhibiting the enzymatic breakdown of complex carbohydrates (*Shobana et al., 2009*). Aldose reductase inhibitors reduce sorbitol accumulation and the occurrence of diabetes-related cataract disease (*Chethan et al., 2023*). A millet-based diet helps to control blood sugar levels and decreases plasma lipid contents in a DM II sick person (*Jali et al., 2012*).

CARDIOVASCULAR DISEASE

Foxtail millet is a good source of soluble and insoluble dietary fiber which helps promote digestive health and alleviates the symptoms of cardiovascular disease and migraines. Foxtail millet contains a variety of phytochemicals, including phytic acid, which has been shown to lower cholesterol (*Coulibaly et al., 2012*). Foxtail millet reduces plasma triglycerides, which may protect against heart disease. According to research, eating whole foxtail millet grains daily reduces the risk of CVD. Furthermore, foxtail millet contains plant lignans, a form of prebiotic fiber that is digested by our digestive system and can be converted to animal lignans by the microflora inside the alimentary canal (*Chun et al., 2010*).

IMMUNITY BOOSTING PROPERTIES

Foxtail millet is a rich source of a generous variety of macro-nutrients such as Ca, Vitamin B1, and Mg. Due to the availability of these macro-nutrients that empower the immune system. Millets are a rich source of high protein, high dietary fiber, vitamins & minerals, anti-oxidants, or micro-nutrients. A strong immune system is crucial for protecting from diseases. To boost immunity it's important to eat a diet rich in minerals vitamins and nutrients. Food like foxtail millet can be very helpful in this regard. Foxtail millet can enhance the immune system and aid our body in fighting certain diseases. For a viral or bacterial infection, adding foxtail millet into the diet can give the strength to fight against diseases (*Coulibaly et al., 2012*).

CANCER

Foxtail millet is a cancer-fighting grain. It is also high in phenol which assists in preventing cancer by preventing the initiation, propagation, and progression of various types of cancer, including colon, lung and breast cancers, which are the leading causes of death today around the world. They also aid in the reduction of tumor size. Foxtail contains several additional phytochemicals antioxidant and anticancer activities, including gallic acid, caffeic acid, and ferulic acid, in addition to these remarkable phenol that protect against cancer. It also helps decrease tumor growth. Foxtail millet has been to have potent antiproliferative properties in human colon cancer cells. The antioxidants found in the bran layer of foxtail help to scavenge damaging free radicals, lowering the risk of cancer. Foxtail consumption has been linked to a lower risk of oesophageal cancer all around the world (*Park et al., 2020*).





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CELIAC DISEASES

Foxtail millet is an excellent cereal for celiac disease prevention. It is naturally gluten-free millet. It is a condition in which gluten causes serious damage to the small intestine and affects gastrointestinal function. As a result, patients must consume exclusively gluten-free foods. As a gluten-free food foxtail millet and their product might be a wonderful alternative for those who are gluten intolerant. A person who is gluten intolerant can also face problem pain, cramps, bloating, etc. It is very beneficial for people who are gluten intolerant (Mereno et al., 2013).

ANTI-INFLAMMATORY

Inflammation is a highlighted feature of any disease and controlling or regulating inflammation-related complications is always on the list of properties when treating chronic diseases such as Asthma, cancer, hypersensitivity, and others. Commercial anti-inflammatory drugs are currently used to target interleukins and interferons, which play important roles in inflammation (Pujari & hoskeri, 2022). Phytochemicals derived from certain minor millets have been shown to have anti-inflammatory and pro-inflammatory properties. Polyphenols in foxtail millet bran extracts suppress the expression of inflammatory cytokines while raising the aspect of inflammatory cytokines by inhibiting nuclear factor-kappa B (NFκB)-p65 nuclear translocation in HT-29 cells. This property of foxtail millet-bound polyphenols aids in the treatment of inflammation. The ethanolic extract of foxtail millet has an anti-inflammatory effect (Hutabarat et al., 2022).

VALUE-ADDED PRODUCTS DEVELOPED FROM FOXTAIL MILLET

Foxtail millet has grown in acceptance in other parts of the world, where it can be consumed in a variety of manners, including breakfast cereal, packaged food snacks, and drinks. Milling foxtail millet concentrates beneficial components, which may subsequently be employed in large-scale production of aspects such as infant meals, supplements, and sweets. Additionally, millet flour can be used to alternatively replace refined wheat flour in the food industry. Several studies have proven that foods developed from foxtail millet have highly favorable nutritional, physical, rheological, and sensory qualities. (Arora et al., 2023) developed kheer, vegetable dalia, pinni, cookies, sattu, rusk, and papad using foxtail millet which reported the the presence of superior nutrient profile, with protein content ranging from 10.98 to 16.10 grams per hundred grams as compared to the products developed from common cereals such as wheat and rice. Whereas, (Uma et a.,2014) developed a bread incorporating foxtail millet with one per overall acceptability with control bread. Foxtail millet was used at 10, 30 and 50 three different percent levels. Developed foxtail millet-based premix helps in controlling diabetes and dyslipidemia in type II diabetic patients. They randomized a study on 300 patients with type II diabetes mellitus for 90 days. They compare the effect of a millet-based diet on glycemic control and plasma lipid concentration. In type II diabetes patients, a high consumption of a millet-based diet improves blood glucose levels and lowers plasma lipid profile (Jali et al.2012). Foxtail millet-based value-added vermicelli as a natural therapeutic health food for people suffering from lifestyle related disorders. This study discovered that substituting foxtail millet, black gram, and fenugreek seeds powder for semolina in vermicelli formulation influenced the physical, chemical, textural, and sensory characteristics of the noodles. The resulting vermicelli showed good pasting properties as well as higher nutritional value with higher fiber content (Pandey et al., 2017). Formulated pasta by using foxtail millet flour and tapioca flour is utilized at various composition levels to formulate pasts. The phytochemicals, cooking efficiency, functional properties and organoleptic acceptability of formed pasta were all assessed When compared to normal pasta, the proximate analysis revealed the highest quantity of dietary fibre, minerals & vitamins, and a significant quantity of fat (Dhas et al., 2021.)

CONCLUSION

Foxtail millet is considered an elite grain with various nutrients and disease-curing benefits. Foxtail millet has been marked for the various micro and macronutrients such as mineral, vitamins, healthy fat, protein, carbohydrates, and phytochemicals. It helps in weight management as well as prevention of non-communicable diseases. It acts as anti-inflammatory, anti-diabetic, anti-microbial, and properties. Foxtail millet can be added to individual diets for





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promotion of health in the form of various value added food products such as cookies, pasta, chocolates , noodles, and papad etc .

REFERENCES

1. Sharma, N., & Niranjana, K. (2018). Foxtail millet: Properties, processing, health benefits, and uses. *Food Reviews International*, 34(4), 329-363.
2. Veerendra, M., Padmaja, B., Reddy, M. M., & Triveni, S. (2021). Yield, Nutrient Uptake, Quality and Economics of Foxtail Millet Cultivation as Influenced by Integrated Nutrient Management with Bacterial Consortia and Liquid Manures. *Int. J. Curr. Microbiol. App. Sci*, 10(03), 1703-1711.
3. Bhavya, P., S. Suchiritha Devi, P. Janaki Srinath, and P. Sreedevi. "Development sensory evaluation of millet-based pizza base." *IJCS* 8, no. 4 (2020): 3502-3504.
4. Maitra, S., Pine, S., Shankar, T., Pal, A., & Pramanick, B. (2020). Agronomic management of foxtail millet (*Setaria italica* L.) in India for production sustainability: A review. *International Journal of Bioresource Science*, 7(1), 11-16.
5. Kuo, S. M., Chen, Y. R., Yin, S. Y., Ba, Q. X., Tsai, Y. C., Kuo, W. H., & Lin, Y. R. (2018). Waxy allele diversification in foxtail millet (*Setaria italica*) landraces of Taiwan. *Plos one*, 13(12), e0210025.
6. Anitha, S., Botha, R., Kane-Potaka, J., Givens, D. I., Rajendran, A., Tsusaka, T. W., & Bhandari, R. K. (2021). Can millet consumption help manage hyperlipidemia and obesity?: a systematic review and meta-analysis. *Frontiers in Nutrition*, 8, 478.
7. Hutabarat, D. J. C., & Bowie, V. A. (2022, February). Bioactive compounds in foxtail millet (*Setaria italica*)-extraction, biochemical activity, and health functional: A Review. In *IOP Conference Series: Earth and Environmental Science* (Vol. 998, No. 1, p. 012060). IOP Publishing
8. Sharma, N., & Niranjana, K. (2018). Foxtail millet: Properties, processing, health benefits, and uses. *Food Reviews International*, 34(4), 329-363..
9. Rathore, S., Singh, K., & Kumar, V. (2016). Millet grain processing, utilization and its role in health promotion: A review. *International Journal of Nutrition and Food Sciences*, 5(5), 318-329.
10. Jha, A. K., Srivastava, A., Raghuvanshi, N. S., & Singh, A. K. (2013). Effect of nitrogen levels on fodder yield and quality of pearl millet genotypes under irrigated condition of Madhya Pradesh. *JNKVV Research Journal*, 47(2), 165-168.
11. Sharma, S., Saxena, D. C., & Riar, C. S. (2015). Antioxidant activity, total phenolics, flavonoids, and antinutritional characteristics of germinated foxtail millet (*Setaria italica*). *Cogent Food & Agriculture*, 1(1), 1081728.
12. Anitha, S., Givens, D. I., Subramaniam, K., Upadhyay, S., Kane-Potaka, J., Vogtschmidt, Y. D., ... & Bhandari, R. K. (2022). Can feeding a millet-based diet improve the growth of children?—A systematic review and meta-analysis. *Nutrients*, 14(1), 225.
13. Dias-Martins, A. M., Pessanha, K. L. F., Pacheco, S., Rodrigues, J. A. S., & Carvalho, C. W. P. (2018). Potential use of pearl millet (*Pennisetum glaucum* (L.) R. Br.) in Brazil: Food security, processing, health benefits and nutritional products. *Food Research International*, 109, 175-186.
14. Srinivasan, A., Ekambaram, S. P., Perumal, S. S., Aruldas, J., & Erusappan, T. (2020). Chemical characterization and immunostimulatory activity of phenolic acid bound arabinoxylans derived from foxtail and barnyard millets. *Journal of food biochemistry*, 44(2), e13116.
15. Shobana, S., Krishnaswamy, K., Sudha, V., Malleshi, N. G., Anjana, R. M., Palaniappan, L., & Mohan, V. (2013). Finger millet (*Ragi*, *Eleusine coracana* L.): a review of its nutritional properties, processing, and plausible health benefits. *Advances in food and nutrition research*, 69, 1-39.
16. Chethan, G. S., Hugar, A. Y., Salimath, S. B., & Kumar, D. (2023). Influence of biostimulants on growth and productivity of foxtail millet (*Setaria italica* L.) genotypes. *Environment Conservation Journal*, 24(3), 109-115.
17. Coulibaly, A., Kouakou, B., & Chen, J. (2012). Extruded adult breakfast based on millet and soybean: nutritional and functional qualities, source of low glycemic food. *J Nutr Food Sci*, 2(151), 2





Nitisha Nainwal et al.,

18. Chun, H. C., Jung, K. Y., Choi, Y. D., Lee, S. H., & Kang, H. W. (2016). The growth and yield changes of foxtail millet (*Setaria italic L.*), proso millet (*Panicum miliaceum L.*), sorghum (*Sorghum bicolor L.*), adzuki bean (*Vigna angularis L.*), and sesame (*Sesamum indicum L.*) as affected by excessive soil-water. *Korean Journal of Agricultural Science*, 43(4), 547-559.
19. Park, S. Y., Jeong, E. W., Yang, Y. S., Kim, H. J., Go, G. W., & Lee, H. G. (2021). Finger millet ethanol extracts prevent hypertension by inhibiting the angiotensin-converting enzyme level and enhancing the antioxidant capacity in spontaneously hypertensive rats. *Antioxidants*, 10(11), 1766.
20. Moreno Amador, M. D. L., Comino Montilla, I. M., & Sousa Martín, C. (2014). Alternative grains as potential raw material for gluten-free food development in the diet of celiac and gluten-sensitive patients. *Austin Journal of Nutrition and Metabolism*, 2 (3), 1-9.
21. Pujari, N., & Hoskeri, J. H. (2022). Minor millet phytochemicals and their pharmacological potentials. *Pharmacognosy Reviews*, 16(32), 101.
22. Zhang, L. Z., & Liu, R. H. (2015). Phenolic and carotenoid profiles and antiproliferative activity of foxtail millet. *Food Chemistry*, 174, 495-501.
23. Xiang, J., Zhang, M., Apea-Bah, F. B., & Beta, T. (2019). Hydroxycinnamic acid amide (HCAA) derivatives, flavonoid C-glycosides, phenolic acids and antioxidant properties of foxtail millet. *Food Chemistry*, 295, 214-223.
24. Devisetti, R., Yadahally, S. N., & Bhattacharya, S. (2014). Nutrients and antinutrients in foxtail and proso millet milled fractions: Evaluation of their flour functionality. *LWT-Food Science and Technology*, 59(2), 889-895.
25. Dey, S., Saxena, A., Kumar, Y., Maity, T., & Tarafdar, A. (2022). Understanding the antinutritional factors and bioactive compounds of kodo millet (*Paspalum scrobiculatum*) and little millet (*Panicum sumatrense*). *Journal of Food Quality*, 2022, 1-19.
26. Longvah, T., Anantan, I., Bhaskarachary, K., Venkaiah, K., & Longvah, T. (2017). *Indian food composition tables* (pp. 2-58). Hyderabad: National Institute of Nutrition, Indian Council of Medical Research.
27. Mounika, D., Sangeetha, U., & Sireesha, G. (2022). Estimation of phytochemicals in millet and selected Millet products. *Indian J. Appl. Pure Bio*, 37, 810-820.
28. Arora, L., Aggarwal, R., Dhaliwal, I., Gupta, O. P., & Kaushik, P. (2023). Assessment of sensory and nutritional attributes of foxtail millet-based food products. *Frontiers in Nutrition*, 10, 1146545.
29. Uma, B., Usha, M., Nirmala, Y., Valerie, O., & Yuvan, G. (2014). Development and quality evaluation of foxtail millet [*Setaria italica (L.)*] incorporated bread. *Karnataka Journal of Agricultural Sciences*, 27(1), 52-55.
30. Jali, M. V., Kamatar, M. Y., Jali, S. M., Hiremath, M. B., & Naik, R. K. (2012). Efficacy of value-added foxtail millet therapeutic food in the management of diabetes and dyslipidemia in type 2 diabetic patients. *Recent Res Sci Technol*, 4(7), 3-4.
31. Pandey, P., Malagi, U., Yenagi, N., & Fatima, A. (2017). Optimization of value-added vermicelli based on Foxtail Millet (*Setaria italica*). *International Journal of Pure & Applied Bioscience*, 5(2), 871-879.
32. Dhas, T. A., Rao, V. A., Sharon, M. E. M., Manoharan, A. P., & Nithyalakshmi, V. (2021). Development of fibre-enriched ready-to-cook pasta with foxtail millet and tapioca flour.

Table 1: Nutritional composition

Nutrient	Quantity per 100g	References
Energy	331	(Longvah et al.,2017),(Dev et al.,2022)
Carbohydrate	60.09	
Protein	12.3	
Fat	4.3	
Moisture	11.2	
Ash	3.3	
Total dietary fibre	2.4	
Thiamine (B1)	0.59	
Riboflavin (B2)	0.11	





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Niacin (B3)	3.2	(Swarnima et al.,2022)
Total Folate (B9)	15	
Magnesium (Mg)	81	
Manganese (Mn)	0.6	
Phosphorous (P)	290	
Iron (Fe)	2.8	
Zinc(Zn)	2.4	
Sodium(Na)	4.6	
Calcium(Ca)	31	

Table 2: Phenolics and Flavonoids

Serial No.	Name of the compound	Phytochemical	Molecular weight	References
1	Xanthophylls	Cartenoids	586.9	(Zhang & liu,2015)
2	Zeaxanthin	Cartenoids	568.88	
3	Vanillic acid	Phenols	338.2	
4	2-methylisocitricacid	Phenols	206.15	(Xiang et al ., 2019)
5	Sinapic acid	Phenols	224.21	
6	Apigenin	Phenols	564.5	
7	Homocitricacid	Phenols	206.15	
8	Ferulictruxillicacid	Phenols	296.3	
9	Trans-p-coumaricacid	Phenols	326.3	
10	Kaempferol	Phenols	286.24	

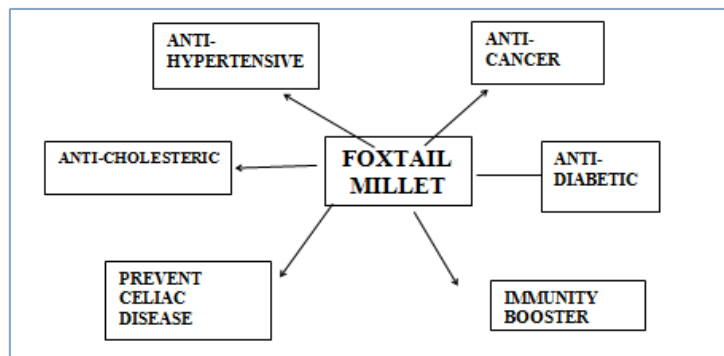


Fig 1: Pharmacological Role of Foxtail Millet

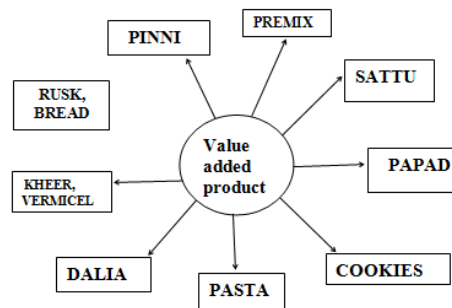


Fig 2: Value-Added Products Developed From Foxtail Millet





Pandemic Accelerated Digitalization of Education: Perspective from Economical Terms

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ABSTRACT

The pandemic of COVID-19 resulted in unprecedented changes in the different fields viz. global, social, economic and educational field since the beginning of 2020. The educational practices and approaches have been altered and resulted in the emergence of digitalization of education. The education has been transformed from the conventional classroom practices to remote distance education involving utilization of digital technologies. The pandemic accelerated the digitalization of education which provides benefits like saving time, learning from anywhere and at any time and missed lectures can be watched from recorded lessons. However, there are certain limitations like not appropriate for students who lack self-discipline, leads to distraction if not used properly, lack of immediate feedback and not a substitute for face-to-face teaching. The present paper highlights digitalization as cost-effective window of opportunities in the time of pandemic and beyond. Digitalization made it possible to produce knowledge and information rapidly which can be processed, communicated and preserved for longer time. The digitalization of economy is primarily realized through methods involving the creation, preservation, dissemination, and use of digital information. It is hoped that with the digitalization of education in the future, the learning process can be made more interactive and interesting.

Keywords: Digitalization, Cost-Effective Window, Online learning, COVID-19, Remote teaching



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INTRODUCTION

Education is the remarkable factor for the economic development as the educated nation advocates the growth and development of economy of any nation. COVID-19 pandemic has resulted in the unprecedented changes in the global, social, economic and educational field since the beginning of 2020. The outbreak of pandemic becomes the pressing issue for the government and distance education has become the only source for providing education. The society all over the globe triggered a dramatic transformation in the form of extensive digitalization (Grek & Landri, 2021). The everyday life and various practices in education have taken a sudden digital leap. The education has been transformed from the conventional classroom practices to remote distance education involving utilization of digital technologies. The whole generation of students started self-regulating their learning activities by mastering use of digital tools. Both teachers and students made significant adjustments so as to continue their education in that challenging time and it also required significant cooperation of parents and administration. Without being prepared for this unprecedented change, schools had to take lead in this digital transformation. Now the situation is normalizing and schools are reopening, the situation of pandemic is still unpredictable. Therefore, the countries should be ready to face any such challenge. Education, as dynamic process, should accept changes and improvements as they arise in response to changing circumstances. Although adapting to changes in this process causes issues, these issues resolve or diminish over time. Digitalization of education has been emerging as a window of opportunities for continuing education in any such unpredictable times. Digitalization of education means use of multimedia and internet technologies for teaching-learning process by exchanging information through these technologies and also using them as source to access various educational resources. Use of digital technologies and technological tools has become the new paradigm of education (Sousa et al., 2020). A new form of collaboration and cooperation has been comprehended among diverse actors of networked society due to the availability of information and communication technologies which enable communication, connectivity and computation in an improved manner (Vial, 2019). The digitalization of education has many benefits like saving time; learning from anywhere and at any time and missed lectures can be watched from recorded lessons. However, there are certain limitations like not appropriate for students who lack self-discipline, leads to distraction if not used properly, lack of immediate feedback and not a substitute for face-to-face teaching. Education, as a dynamic process, should accept changes and improvements that can be implemented as needed in response to changing conditions. Although adapting to changes in this process causes issues, these issues resolve or diminish over time (Babacan & Yuvarlakbas, 2022). The use of innovative teaching strategies and techniques such as video-based learning, team-based learning, and peer teaching has become mandatory in the process of COVID-19 pandemic for continuing education. It is hoped that with the digitalization of education in the future, the learning process can be made more interactive and interesting.

Theoretical Framework

The spread of COVID pandemic disrupted the education system all around the globe. UNESCO reported that pandemic affected education of 1.6 billion students in more than 190 countries. Schools and other Educational Institutions had switched all the teaching learning activities to digital online mode of learning. Although initially teachers and students faced difficulties in handling these digital tools but with time, they get used to it. Digital learning and skills must be incorporated in order to accomplish the needs of education in future. Gond and Gupta (2017) reported that India has launched Many digital initiatives in the form of Digital Education programs with varied level of implementation. The global online education market was expected to grow at an annual rate of 8.2% in 2019, but COVID-19 made significant changes to its projected growth values. Analysts predict that the total online educational market will grow nearly tenfold within a year and previously it was predicted that its growth will slow down after reaching a high level. However, contrary to that its growth rate increases at extremely high level. Research and Market (2022) in their report on Online education market reported that the annual expenditure on online education will increase by 17.19% from 2021-2026. Digital learning is an efficient way to cut costs, maximize resource Utilization, and expand the reach and influence of students and educators. There are numerous digital platforms, tools, and technologies available to help promote education at all levels (Kumar, 2021). Tools such as



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Google Classroom, Zoom, GoToMeeting, and Microsoft Team all offer a communication network platform through which teachers and students can communicate. WhatsApp is another popular tool. E-learning and e-learning tools play a major platform for enhancing learning of students in the time of pandemic. Most of these tools are free and therefore are helpful in providing continuing education in the time of pandemic (Subedi et al., 2020). The digitalization process makes the invisible visible. Several users can access the same document at the same time without difficulty. It also eliminates the need for users to travel to locations that have the technology.

Digitalization and Education

Digitalization of education is not a new phenomenon and it has been in the picture before the pandemic (Adedoyin & Soykan, 2020). However, the COVID-19 pandemic accelerated this digitalization of education. Schools and universities were never completely closed because education could rely on digital infrastructures, platforms, and software. Remote teaching in the form of digital learning provided emergency educational practices and despite the collapse of educational institutions in pandemic, these digital platforms made education to continue in the situation of emergency. For continuing education, Higher Education Institutions (HEIs) are rapidly adopting alternative pedagogies for engaging students in the learning process in the virtual mode (Pujari, 2020). Digitalization of education reshapes educational practices by allowing for manipulation, experimentation, and coordination among various institutions and stakeholders, all of which can expand the possibilities for teaching and learning. As a result, the pandemic provided an opportunity to advance the digitalization in education. Many academics see the emergency remote learning as a chance to digitally transform universities, which will have a positive impact on teaching methods (Zawacki-Richter, 2021). Digitalization of education necessitates expert training, planning and design. Teachers' responsibilities have become increasingly diverse and specialized, necessitating an expansion of their knowledge and skills (Baliya et al., 2022). Teachers must be exposed to using technology in the teaching-learning process in order to instill 21st-century skills in students.

Changing Forms of Education in the Time of Pandemic

The pandemic provides opportunities to both teachers and students to critically consider the future of education. World Education Forum (2020) pointed out that there is paradigm shift in the process of teaching and learning. The Utilization of online teaching learning practices during pandemic provides alternative ways of curriculum transaction and thus resulted in innovative teaching learning practices. Mhlanga and Moloi (2020) asserted that the change occurring in the educational paradigm is just beginning of the process and will be ultimately moved to mostly digital and occasionally face-to-face. Thus, pandemic has transformed the teaching learning process by utilizing digital tools and innovative teaching strategies. There is a variety of educational technologies and tools that can be used for teaching this changing educational paradigm of pandemic. Smart phones, networking software (e.g., Hangouts, WhatsApp, Skype), and open educational resources such as Khan Academy are examples of these. Collaborative tools (such as blogs, wikis, and knowledge-building software), immersive environments (such as virtual worlds), media production and distribution tools, and many more are examples of tools for learning organizations.

Digitalization as Cost Effective Window of Opportunities for Education in the time of Pandemic

The concept of digitalization is introduced as a result of developments in the field of ICT (Information and Communication Technologies). For communicating vast amount of information to a larger community, internet has played a significant role whereby a shift from print to digital media has provided wider and rapid access to information. Digitalization made it possible to produce knowledge and information rapidly which can be processed, communicated and preserved for longer time. The digitalization economy is primarily realised through methods involving the creation, preservation, dissemination, and use of digital information. For today's society, information digitization appears to be quite valuable and cost-effective. However, the digitalization process is not considered economical in its early stages, the low-cost impact can be realised later on, in terms of increasing returns, zero marginal cost, and long-term usage of digitised content by the larger community (Khan et al, 2015). Designing a website, creating an educational video, designing an educational course, designing a website are costly at initial stage however in long terms, it is a very cost-effective as fast software and hardware packages, good internet connectivity



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and migration to new technology has cut the production costs. The fixed or first copy cost of digitising the work, the computer system, and the effective flow of information over the internet is the primary cost. Printing multiple copies of a single document has a low marginal cost. Although digitalization has long-term societal benefits, it may take years to fully realise these benefits. As a result, the digitalization economy involves short-term investments that yield long-term benefits. E-education has the potential to reduce tuition because online and technology-enabled systems require fewer expenses for maintaining buildings and paying staff and faculty and allow for larger classes. The information delivery system in this changing era of pandemic affected world is transformed in the form of electronic sources. Electronic sources include e-learning platforms, use of learning management system, access to e-journals, online databases, consortiums etc. saves much money than those involved with subscription and purchase of print resources. The coverage of electronic digital resources is very vast. e.g., an online educational video can be viewed by large number of learners than the lecture delivered in compartmentalized classroom. Purchasing information online, rather than in print, saves a significant amount of money. Because the costs of purchasing print sources include storing, shelving, and the costs of physical storage of the content, which are direct costs to the organizations. The transition to electronic content has reduced the cost of maintaining physical materials while slightly increasing the cost of preserving them. Therefore, digitalization is emerging as a cost-effective window which provided significant opportunities in the time of pandemic to continue education in lockdown and beyond.

Implications for Future

The pandemic has highlighted the potential of a digital transformation of education. It has accelerated the process of digitalization of educational process, practices and resources. Digital tools and resources can improve quality and efficiency of education and reshape the structure of formal education only if they are used by stakeholders effectively under the governmental policies and recommendations (OECD, 2021). The power of digital technology has been demonstrated in the pandemic through online learning in distance mode. In the future online learning will serve as an essential component of educational institutions for continuing education. A blended learning model can incorporate advanced pedagogies as well as digital technology-based teacher-student engagement. The National Education Policy (NEP, 2020), focuses on use of technology and also provides policy framework for inclusion of technology in education. Both online and offline learning methods can be incorporated through digitalization which focuses on technology, provides a policy framework for this. The future of education is use of hybrid mode of learning. The educational resources can be preserved over generations with the help of digital tools. As a result, in the twenty-first century, the digitization of the education industry proves to be a boon to our society. According to a recent market research analysis published by Inkwood Research, the Global Smart Education & Learning System Market is estimated to produce \$1194.73 billion in revenue by 2028 at a CAGR of 16.61%.

DISCUSSIONS AND CONCLUSION

The distinction between distance education and emergency distance education should be considered during the COVID-19 pandemic period, because distance education began with no preparations. If the flaws caused by emergency distance education can be identified and the pandemic process is prolonged, these flaws should be addressed as much as possible. Distance education should be beneficial in accordance with its purpose if both educators and students are aware of its principles. Digital tools, augmented virtual reality, and virtual dissection tables are examples of technological applications that have entered our lives as technology has advanced. Instead of lecturing directly in online classes to ensure student participation and to create a classroom environment, a more interactive method should be used. Digitalization is an all-encompassing preservation and access technique that entails converting all of the institution's assets into digital and accessible formats. Emerging digitalization initiatives and digitalization methods for institutions are having a wide range of consequences for the economy, society, and academia. Information presentation and distribution are now more rapid, open, and global than ever before as a result of these radical and rapid changes. Additionally, converting analogue to digital material lowers some of the costs associated with digitalization operations that provide access to print sources.





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REFERENCES

1. Adedoyin, O. B., & Soykan, E. (2020). COVID-19 pandemic and online learning: the challenges and opportunities. *Interactive learning environments*, 1-13. <https://doi.org/10.1080/10494820.2020.1813180>
2. Babacan, S. & Yuvarlakbas, S. D. (2022). Digitalization in education during the COVID-19 pandemic: emergency distance anatomy education. *Surg Radiol Anat*, 44(1), 55-60. <https://doi.org/10.1007/s00276-021-02827-1>
3. Baliya, J.N., Thappa, S.R. & Shikha, D. (2022). Efficacy of TPACK Framework through Blended Learning Approach: An Innovative Integrated Model in Post COVID-19 Era. *Education India: A Quarterly Refereed Journal of Dialogues on Education, A UGC- CARE List Journal*, 11(4). <http://www.educationindiajournal.org>
4. Gond, R. & Gupta, R. (2017). A study on digital education in India: Scope and challenges of Indian society. *Anveshana's International Journal of Research in Regional Studies, Law*, 2(3), 12-18.
5. Grek, S., & Landri, P. (2021). Education in Europe and the COVID-19 Pandemic. *European Educational Research Journal*, 20(4), 393-402. <https://doi.org/10.1177/147490412111024781>
6. Khan, S., Khan, S., & Aftab, M. (2015). Digitalization and its impact on economy. *International Journal of Digital Library Services*, 5(2), 138-149.
7. Kumar, S. (2021). Potential of digital initiatives for school education in India during COVID-19 pandemic. *International Journal of Multidisciplinary Educational Research*, 10 (9),3. <http://ijmer.in.doi./2021/10.09.42>
8. Mhlanga, D., & Moloi, T. (2020). COVID-19 and the Digital Transformation of Education: What Are We Learning on 4IR in South Africa? *Education Sciences*, 10(7), 180. <https://doi.org/10.3390/educsci10070180>
9. OECD (2021), OECD Digital Education Outlook 2021: Pushing the Frontiers with Artificial Intelligence, Blockchain and Robots, OECD Publishing, Paris, <https://dx.doi.org/10.1787/589b283f-en>.
10. Pujari, A. K. (2020). A pandemic pedagogy to overcome COVID disruptions. <https://www.livemint.com.cdn.ampproject.org/v/s/www.livemint.com/opinion/online-views/a-pandemic-pedagogy-to-overcome-COVID-disruptions/amp-11588933646265>
11. Research and Markets (2022, Feb 15). Online Education Market in India 2022. Cision PRNewswire. *Social Sciences Journal of Management Practices*, 2 (3), 12-18. <https://www.researchandmarkets.com/reports/5522535>
12. Sousa, R. D., Karimova, B., & Gorlov, S. (2020). Digitalization as a new direction in education sphere. In E3S Web of Conferences (Vol. 159, p. 09014). *EDP Sciences*. <https://doi.org/10.1051/e3sconf/202015909014>
13. Subedi, S., Nayaju, S., Subedi, S., Shah, S. K., & Shah, J. M. (2020). Impact of E-learning during COVID-19 pandemic among nursing students and teachers of Nepal. *International Journal of Science and Healthcare Research*, 5(3), 68-76.
14. Vial, G. (2021). Understanding digital transformation: A review and a research agenda. *Managing Digital Transformation*, 13-66.
15. World Economic Forum. (2020). The Future of Jobs Report 2020. <https://www.voced.edu.au/content/ngv:88417>





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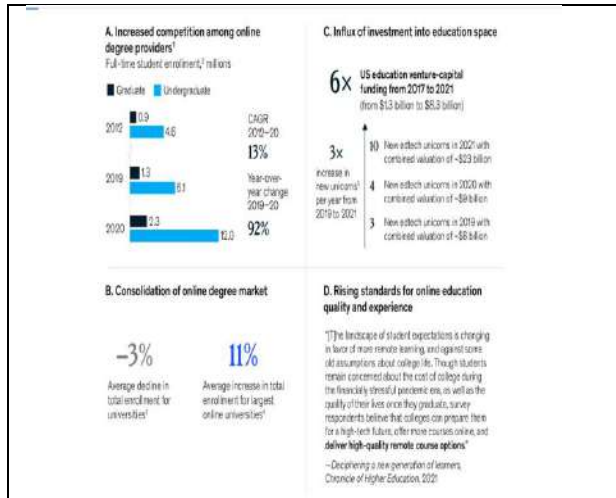


Figure 1: (Source: Deciphering a new generation of learners, Chronicle of Higher Education, 2021)

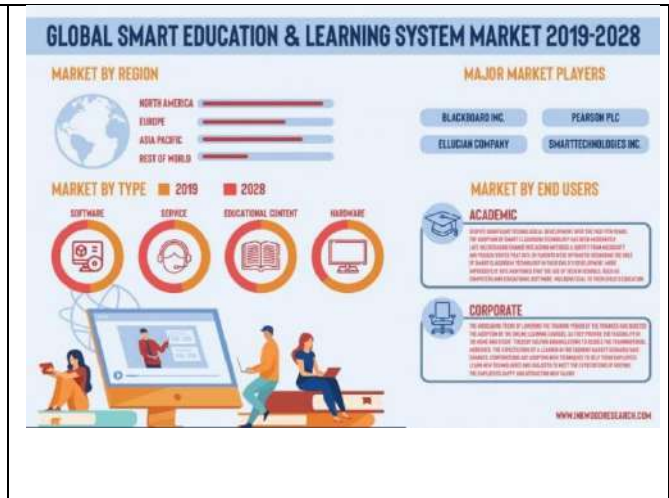


Figure 2





Development and Evaluation of Gel Derived from Natural Sources for the Treatment of Inflammation

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ABSTRACT

The predominant use of natural ingredients by approximately 75-80% of the global population, particularly in developing nations, remains integral to primary healthcare. This preference stems from several factors including cultural acceptability, compatibility with the human body, and reduced incidence of side effects. Consequently, our current research endeavours to evaluate and standardize selected plant drugs—namely *Rosa indica*, *Calotropis procera*, and *Adhatoda vasica*—for their purported anti-inflammatory properties as described in traditional systems of medicine. The ultimate goal is to develop a polyherbal formulation harnessing the therapeutic potential of these plants. The in-vitro studies conducted to assess the anti-inflammatory activity of all three plants utilized assays targeting two pro-inflammatory cytokines, IL-4 and TNF- α , along with two anti-inflammatory cytokines, IL-10 and IL-6. Both alcoholic and aqueous extracts of *Adhatoda vasica*, *Rosa indica*, and *Calotropis procera* were tested. Results from these in-vitro studies revealed that the aqueous extracts of all three plants exhibited significant anti-inflammatory activity. Following these promising findings, a polyherbal gel formulation was developed, comprising a base composed of Carbopol 934, Triethanolamine, Polyethylene glycol, Methyl paraben, Propyl paraben, water, and a mixture of aqueous extracts from *Adhatoda vasica*, *Rosa indica*, and *Calotropis procera*. Subsequent in-vivo studies conducted on rats were aimed at evaluating the efficacy of our polyherbal gel formulation. Skin irritation studies and a Carrageenan-induced paw edema model were employed to assess anti-inflammatory activity. The results demonstrated a remarkable inhibition of edema, with the Polyherbal Gel exhibiting a 67.3% inhibition, surpassing the effectiveness of





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the standard Diclofenac Gel, which showed a 61.66% inhibition. These findings underscore the potent anti-inflammatory effect of our polyherbal gel formulation.

Keywords: Anti-inflammatory, Polyherbal Gel, *Adhatoda vasica*, *Rosa indica*, *Calotropis procera*

INTRODUCTION

Inflammation is an innate immune response that is triggered due to a stimulus that is capable of disrupting homeostasis. This stimulus can be either biotic (pathogen) or of abiotic (allergen or chemical or irradiation) origin. Inflammation ensures restoration of homeostasis by the removal of the stimulus as well as the cells effected by it. An appropriate and proper inflammatory response depends on the careful regulation of several mediators such as cytokines, which are secreted by inflammatory cells such as macrophages and neutrophils. Macrophages are known to play a pivotal role in the host's defense against harmful materials and are involved in a variety of diseases including autoimmune diseases, pathogenic infections, and inflammatory disorders. An inflammatory stimulus such as lipopolysaccharide (LPS) can activate macrophages to produce a variety of pro-inflammatory cytokines such as interleukin-1 β (IL-1 β), IL-6, and tumor necrosis factor- α (TNF- α), and other inflammatory mediators.[1,2,3] The excessive activation of macrophages can induce the production of several kinds of pro-inflammatory enzymes and cytokines, which may lead to chronic inflammatory diseases like rheumatoid arthritis. Pro-inflammatory cytokines, such as tumour necrotic factor (TNF)- α , interleukin (IL)-1 β , and IL-6, are mainly produced in macrophages activated by gram negative bacteria-derived lipopolysaccharide (LPS). TNF- α plays an important role in the promotion of inflammatory response, which in turn causes many clinical problems associated with autoimmune disorders, such as rheumatoid arthritis, Crohn's disease, psoriasis, and asthma. IL-6 plays an important role in the induction of acute phase reactions.^[4] In this study, I compared the anti-inflammatory activity of methanolic and aqueous extracts of *Adhatoda vasica*, *Calotropis procera* and *Rosa indica* and clarified the mechanism for anti-inflammatory activities of flavonoids in the LPS induced inflammatory responses of murine macrophages. The present work therefore aimed to evaluate and standardize the selected plant drugs such as *Rosa indica*, *Calotropis procera* and *Adhatoda vasica* for the claims made under traditional systems for their **anti-inflammatory activities** and prepare **polyherbal formulation**.

PLANT PROFILES

Adhatoda vasica Nees. (also known as *Justicia adhatoda* L.) is a shrub belonging to the family, Acanthaceae. The plant is being used in India and many South Asian countries for centuries, as part of various Ayurvedic and Siddha formulations. *Vasica* contains phytochemicals such as alkaloids, glycosides, sterols, and phenolic acid. Alkaloids (quinazoline) betaine, steroids, carbohydrate and alkanes are the most common constituents. Pharmacological Properties are Antibacterial activity, Anti-asthmatic activity, Anti-diabetic activity, Anticancer activity, Insecticidal activity, Thrombolytic and cardioprotective activity, Antitussives, Anti-tuberculosis activity, Analgesic activity, Uterine Activity, Hepatoprotective Activity, Anti-inflammatory, Antioxidant activity, Anthelmintic activity, Wound healing activity, Anti-Alzheimer Activity, Anti-Ulcer activity, Antiviral activity, Anti-allergic activity, Anticholinesterase activity, Antifungal activity ^[11,14,15]

Rosa indica belongs to the family of Rosaceae. It is known for various pharmacological activities, and the presence of coloured pigments and chemical constituents like flavonoids. It is also valued for their culinary, medicinal, cosmetic, and aromatic properties. Medicinal Actions of Rose are Antidepressant, Antispasmodic, Aphrodisiac, Astringent, Antibacterial, Antiviral, Antiseptic, Anti-inflammatory, Blood tonic, Cleansing, Digestive stimulant, Expectorant, Increases bile production, Kidney tonic, Menstrual regulator.^[13]





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Calotropis procera (Ait) R. Br. is well known for its traditional medicinal uses belonging to the family Asclepiadaceae. It has numerous colorful names such as Sodom Apple, Akund Crown flower and Dead Sea Fruit, but the scientific name is *Calotropis procera*. The leaves were reported to contain calotropagenin, calotropin, calotoxin, calactin, α -amyrin, β -amyrin, stigmaterol, calotropenyl acetate, calotropenol, procesterol, uscharin, voruscharin, syriogenin, 16 α -hydroxy calotropagenin, ursolic acid, and *o*-pyrocatechuic acid etc. [5,8,9,10]

MATERIALS AND METHODS

Plant materials.

The leaves of *Calotropis procera* and *Adhatoda vasica* was procured from the medicinal garden of The Maharaja Sayajirao University of Baroda, while the flower petals of *Rosa indica* were acquired from the Vadodara market. The Botany Department at The M.S. University of Baroda authenticated the identification of all plant materials. Voucher specimens of these herbs have been submitted to the Pharmacy department at The M.S. University of Baroda.

Preparation of powdered material

The selected plant materials were collected, cleaned to remove any adhering material and then dried in shade. The large, dried plant parts were then subjected to size reduction to coarse powder and used for further studies.

Preparation of extracts

The dried powder of plant was extracted with various solvents. Aqueous extract and methanolic extract of three selected plants were obtained using Soxhlet apparatus. About 20 gm of dried powder of plant part was subjected to Soxhlet apparatus for 36 hours. The temperature was maintained at 40 degrees centigrade. The solvents were removed by heating at low temperature on water bath and got semi solidmass.

Qualitative analysis of extracts

The phytochemical screening of the plant materials was done by qualitative chemical tests. Qualitative chemical tests were performed for methanolic and aqueous extracts of *Calotropis procera*, *Rosa indica* and *Adhatoda vasica*.

Cell viability study and Evaluation of anti-inflammatory activity of extracts by in-vitro method

Cell culture

Human monocyte (THP-1) cell line was obtained from National Centre for Cell Science (NCCS), Pune, Maharashtra, India and maintained in RPMI-1640 medium (HiMedia Laboratories, Mumbai, India) supplemented with L-glutamine (2 mmol/l), 10% FBS (Gibco, Thermo Fisher Scientific, USA) and 1 \times antibiotic-antimycotic solution (HiMedia Laboratories, Mumbai, India) in a humidified atmosphere with 5% CO₂ at 37 °C. For the induction of cell differentiation, THP-1 cells (1.5 \times 10⁶ per ml) were seeded in serum-free RPMI-1640 with 50 nM PMA for 24 h. After incubation, non-adherent cells were removed by aspiration, and the adherent THP-1 derived macrophages (TDMs) were washed with PBS before experimental treatments.

Cell viability assay

Cell viability was assessed by MTT (3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide) assay. After experimentation, the cells were washed with PBS, followed by addition of 0.5 mg/ml MTT to each well and incubation at 37 °C for 4 h. The purple formazan crystals formed were dissolved in DMSO and the absorbance was recorded at 590 nm using Synergy HTX Multimode Microplate Reader (BioTek Instruments Inc., USA). The results were represented as percentage cell viability with respect to control.

Evaluation of anti-inflammatory activity of extracts

ELISA of TNF- α , IL-4, IL-6 and IL-10

Conditioned media from cells was collected and centrifuged at 800 \times g for 5 min to remove cellular debris. Levels of TNF- α , IL-4, IL-6 and IL-10 in conditioned media were detected using an ELISA kit according to





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manufacturer's protocol (Krishgen). The concentration of TNF- α , IL-4, IL-6 and IL-10 in samples was determined from standard curve using GraphPad Prism 6.0.

Development of Polyherbal formulation

Preparation of Optimized Polyherbal gel

The gel was prepared using the dried extract of *Adhatoda vasica*, *Rosa indica* and *Calotropis procera*. The gel was prepared using Carbapol-934 (1%), polyethylene glycol, methyl paraben, propyl paraben, tri-ethanolamine, and distilled water in a quantity sufficient to prepare 100 g of gel. Water required for these formulations was divided in to two parts. In one part the exact quantity of extracts were dissolved and in other part, carbapol-934 was dissolved and to this solution methyl paraben and propyl paraben were added. Both solutions were mixed in a beaker and tri-ethanolamine was added to the mixture dropwise to obtain the gel consistency.

Evaluation of Polyherbal gel formulation

pH measurement

pH measurement of the gel was carried out using a digital pH meter by dipping the glass electrode completely into the gel system to cover the electrode. The measurement was carried out in triplicate and the average of the three readings was recorded.

Appearance and Homogeneity

Physical appearance and homogeneity of the prepared gels were evaluated by visual perception.

Viscosity

Viscosity of gel was determined using Brookfield viscometer (S-62, model DV-1) at 25 °C with a spindle speed of the viscometer rotated at 12 rpm.

Spreadability

Two sets of glass slides of standard dimensions were taken. The herbal gel formulation was placed over one of the slides. The other slide was placed on the top of the gel, such that the gel was sandwiched between the two slides. Hundred g weight of gel was placed on the upper slides so that the gel was between the two slides was pressed uniformly to form a thin layer.

Assay

Quantification of herbal markers in Gel formulation by HPTLC method

The polyherbal gel was quantified using High-Performance Thin-Layer Chromatography (HPTLC) method, employing markers such as vasicine, gallic acid, and rutin.

Assessment of anti-inflammatory effect of formulation

Skin irritation study(MSU/IAEC/2021-22/2117)

This test was performed on Wistar/Sprague-Dawleyrats. The animals given standard animal feed and had free access to water ad libitum. Animals were divided into three groups, each batch containing six animals. Dorsal hairs at the back of the rats were removed one day prior to the commencement of the study and kept individually in cages to avoid contact with the other rats. Two groups of each were used for control and standard irritant. Another group was used as a test. The 50 mg of the formulation was applied over one square centimeter area of whole and abraded skin of different animals. Aqueous solution of 0.8% formalin was used as standard irritant. The animals were observed for 10 days for any signs of edema and erythema.





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Evaluation of anti-inflammatory activity

Male or female Sprague-Dawley or Wistar rats were used. The animals were starved overnight. To ensure uniform hydration, the rats received 5 ml of water by stomach tube (controls) or the test drug dissolved or suspended in the same volume. Thirty minutes later, the rats were challenged by a subcutaneous injection of 0.05 ml of 1% solution of carrageenan into the plantar side of the left hind paw. The paw was marked with ink at the level of the lateral malleolus and immersed in water up to this mark. The paw volume was measured plethysmo graphically immediately after injection, again 3 and 6 h, and eventually 24 h after challenge.

RESULTS AND DISCUSSION

Qualitative Phytochemical Screening of extracts

- AVM- *Adhatoda vasica* Methanolic extract
- AVA- *Adhatoda vasica* Aqueous extract
- RIM- *Rosa indica* Methanolic extract
- RIA- *Rosa indica* Aqueous extract
- CPM- *Calotropis procera* Methanolic extract
- CPA- *Calotropis procera* Aqueous extract

The physico-chemical parameters evaluation showed presence of saponins, alkaloids, flavonoids, glycosides and other chemical classes in both aqueous and alcoholic extracts of all three plants.

Qualitative test by HPTLC

The HPTLC analysis was also performed for the development of characteristic fingerprint profile, which may be used as markers for quality evaluation and standardization of the drug. The R_f value for Vasicine was 0.78 in *Adhatoda vasica*, for Rutin was 0.25 in *Rosa indica* and for Gallic acid was 0.31 in *Calotropis procera*. (Figure.1A,1B,1C).

Cell viability assay

Cell viability assay was performed to determine the potential level of toxicity produced by all extracts on THP-1 cell line. The results for cell viability assay showed that individual aqueous extracts of all three plants were better than individual alcoholic extracts in terms of cell survival at higher concentration ranges. The cells were found to be viable in the presence of mixture of all three aqueous extracts of plants however mixture of methanolic extracts were found to be toxic to cells. Cell viability was not affected by any of the plant extract and also mixture of all three plant extracts as measured by MTT assay. These results indicate that no lethality or local toxicity were observed after administration 500 $\mu\text{g/ml}$ of dose. Only there was some lethality with the *Rosa indica* methanolic extract above 100 $\mu\text{g/ml}$ of dose.

ELISA of TNF- α , IL-4, IL-6 and IL-10

IL-4 assay

Based on graphs, *Rosa indica* aqueous extract treatment showed higher IL-4 inhibition activity compared to the other extracts. It can be seen that all other aqueous extracts were able to inhibit IL-4 production in LPS-induced cells. The LPS induction was successfully increase the IL-4 concentration, showed by significantly high IL-4 level in positive control (LPS-induced cells without treatment) compared to the negative control (normal cells without LPS induction).

IL-10 assay

Based on graphs, *Calotropis procera* aqueous extract treatment showed higher IL-10 concentration as compared to the other extracts. So, it indicates best anti-inflammatory activity than other extracts. Other aqueous extracts were able to increase IL-10 production in LPS-induced cells. The LPS induction was successfully decrease the IL-10 concentration, showed by significantly low IL-10 level in positive control (LPS-induced cells without treatment) compared to the negative control (normal cells without LPS induction).





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CONCLUSION OF IN-VITRO STUDY

The in-vitro studies performed to assess anti-inflammatory activity of all plants were done using assay of two pro-inflammatory cytokines IL-4 and TNF- α and two anti-inflammatory cytokines IL-10 and IL-6. The experiment was performed using both alcoholic and aqueous extracts of all three individual plants. The levels of IL-4 were considerably reduced in the presence of aqueous extracts of all three plants whereas results for TNF- α were ambiguous since it showed increased levels in presence of all extracts. The levels of IL-6 were not detected in control as well as LPS induced inflammation hence was dropped out due to not satisfactory results. The levels of IL-10 were increased more in presence of aqueous extracts of all three plants as compared to alcoholic extracts. Hence it was concluded that effect of all three aqueous extracts had better anti-inflammatory effect as compared to alcoholic extracts. The results of cell viability studies and in-vitro anti-inflammatory activity led to selection of aqueous extracts of all three plants.

Development of Polyherbal gel

Gel was selected for development owing to ease of patient compliance. Poly-herbal gel was composed of base consisting of Carbopol 934, Triethanolamine, Polyethylene glycol, Methyl paraben, Propyl paraben, water and mixture of aqueous extracts of all three plants. Evaluation of poly-herbal gel was performed and satisfactory compliance for evaluation parameters was obtained.

Evaluation of Polyherbal gel

Skin irritation test

The prepared herbal gel and herbal spray were evaluated for its skin irritant effect, where no erythema or edema was observed for all the formulations, even after 10 days of study, indicating that the prepared herbal gel formulation and spray were found to be safe.

Evaluation of anti-inflammatory activity

The pharmacological screening was carried out by using the carrageenan-induced edema model to evaluate the possible anti-inflammatory activity of the Polyherbal Gel formulation. As shown in Table, the inhibition of edema was 67.3% for Herbal Gel, highly effective to that produced by the standard Diclofenac Gel 61.66%, indicating an anti-inflammatory effect. We have systematically developed and evaluated a polyherbal formulation for inflammatory conditions, shedding light on its efficacy, safety, and potential therapeutic benefits. Our investigation involved utilizing aqueous extracts of *Rosa indica*, *Adhatoda vasica*, and *Calotropis procera*, all of which exhibited anti-inflammatory activity by significantly reducing the production of pro-inflammatory cytokines IL-4 and TNF- α in activated THP-1 cells. We propose that the mechanisms underlying these extracts' effects may involve the inhibition of inflammatory mediator overproduction, including TNF- α and IL-4, while concurrently increasing levels of IL-10, which exerts anti-inflammatory effects. The gel formulation was chosen for development due to its favourable characteristics for patient compliance. Our polyherbal gel was formulated with a base composed of Carbopol 934, Triethanolamine, Polyethylene glycol, Methyl paraben, Propyl paraben, water, and a mixture of aqueous extracts from all three plants. Evaluation of the polyherbal gel was conducted, and satisfactory compliance with evaluation parameters was achieved. This indicates that the gel formulation meets the necessary standards for quality and consistency. Furthermore, in vivo studies conducted on rats aimed to assess the efficacy of our polyherbal gel formulation. Skin irritation studies and a Carrageenan-induced paw edema model were employed to evaluate anti-inflammatory activity. Results from these in vivo experiments demonstrated that the polyherbal gel's effectiveness surpassed that of Diclofenac Gel, a standard anti-inflammatory medication. Overall, our developed polyherbal formulation presents several advantages, including plausible anti-inflammatory activity, utilization of natural sources, avoidance of chemical harm associated with conventional formulations, ease of patient compliance, and cost-effectiveness. These findings suggest promising therapeutic potential for managing inflammatory conditions with our polyherbal formulation.





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REFERENCES

1. Yang et al. / J Zhejiang Univ-Sci B (Biomed & Biotechnol) 2010 11(5):315-322
2. Prasanth Ghanta, Shweta Sinha, Mukesh Doble & Basavaraju Ramaiah (2020): Potential of pyrroquinazoline alkaloids from *Adhatoda vasica* Nees. as inhibitors of 5-LOX – a computational and an in-vitro study, *Journal of Biomolecular Structure and Dynamics*, DOI: 10.1080/07391102.2020.1848635.
3. Franceschi, C.; Campisi, J. Chronic Inflammation (Inflammaging) and Its Potential Contribution to Age-Associated Diseases. *J. Gerontol. Ser. A Biol. Sci. Med. Sci.* **2014**, *69*, S4–S9.
4. Jae Kwon Lee, Anti-inflammatory Effects of Eriodictyol in Lipopolysaccharide stimulated Raw 264.7 Murine Macrophages, *Arch Pharm Res* Vol 34, No 4, 671-679, 2011, DOI 10.1007/s12272-011-0418-3
5. YOGESH MURTI*, SAURABH SHARMA, PRADEEP MISHRA, IN VITRO ANTHELMINTHIC ACTIVITY OF CALOTROPIS PROCERA (AIT.) R. BR. LEAVES, *Asian journal of Pharmaceutical and clinical research*, Vol 8, Issue 6, 2015
6. Lawrence, T., Willoughby, D. A., & Gilroy, D. W. (2002). Anti-inflammatory lipid mediators and insights into the resolution of inflammation. *Nature Reviews Immunology*, *2*(10), 787–795. doi:10.1038/nri915
7. Joerg Gruenwald, Ralf Uebelhack and Margret Irmgard Moré, *Phytomedicine*,
8. <https://doi.org/10.1016/j.phymed.2019.152958>
9. Mali RP, Rao PS, Jadhav RS, A Review on Pharmacological Activities of *Calotropis Procera*, *Journal of Drug Delivery and Therapeutics*. 2019; *9*(3-s):947-951 <http://dx.doi.org/10.22270/jddt.v9i3-s.2870>
10. Ali Esmail Al-Snafi, The constituents and pharmacological properties of *Calotropis procera* - An overview, *International Journal of Pharmacy Review & Research*, Vol 5, Issue 3, 2015, 259-275
11. Bhumika Yogi*, Sujeet Kumar Gupta and Ashutosh Mishra, *Calotropis procera* (Madar): A Medicinal Plant of Various Therapeutic Uses-A Review, *Bull. Env. Pharmacol. Life Sci.*, Vol 5 [7] June 2016: 74-81
12. Rastogi, R. & Mehrotra, B. (1999). *Compendium of Indian medicinal Plant*. Central drug research Institute Lucknow, National Institute of Science, New Delhi, Vol. 2, 1st Edn., p. 147
13. Murti, Y., Yogi, B. & Pathak, D. (2010). Pharmacognostic Standardization of Leaves of *Calotropis procera* (Ait.) R.Br. (Asclepiadaceae). *Inter. J. Ayur. Res.*, *1*(1): 14-17
14. Thakare Priya Ashokrao, Deshbhatar Kiran, Suryawanshi M.N. A Brief Review on Therapeutic Effects of – “Ornamental Plant” Rose. *International Journal of Ayurveda and Pharma Research*. 2017; *5*(12):46-52.
15. Md. Tofazzal Hossain Md., Obydul Hoq, Therapeutic use of *Adhatoda vasica*, *Asian J. Med. Biol. Res.* 2016, *2* (2), 156-163; doi: 10.3329/ajmbr.v2i2.29005
16. Shah Unnati, Pharmacognostical and Phytochemical Evaluation of *Adhatoda vasica* Leaf, *International Journal of Research Studies in Biosciences (IJRSB)* Volume 2, Issue 11, December 2014, PP 144-148
17. Ambreen Shoaib, A systematic ethnobotanical review of *Adhatoda vasica* (L.), Nees., *Cellular and molecular biology*.
18. World Health Organization, *Quality Control methods for medicinal plant materials*,
19. Geneva 1998. 198.
20. World Health Organization, *Guidelines for the assessment of Herbal medicines*, Annex 11, WHO Technical Report series No.863, (1996).
21. *Indian Pharmacopoeia*, Government of India, Ministry of Health and Welfare, Controller of publication, Delhi, (1966), 708 pp.





Preeti Jadeja et al.,

22. Ajay Kumar Meena *, Ajay Yadav, M M Rao, Ayurvedic uses and Pharmacological activities of *Calotropis procera* Linn. / Asian Journal of Traditional Medicines, 2011, 6 (2)
23. Prasanth Ghanta , Shweta Sinha , Mukesh Doble & Basavaraju Ramaiah(2020): Potential of pyrroquinazoline alkaloids from *Adhatodavasica* Nees. as inhibitors of 5-LOX– a computational and an in-vitro study, Journal of Biomolecular Structure and Dynamics, DOI:10.1080/07391102.2020.1848635
24. Syed Murthuza, B.K. Manjunatha, In vitro and in vivo evaluation of anti-inflammatory potency of *Mesua ferrea*, *Saracaasoca*, *Viscum album* & *Anthocephalus cadamba* in murine, macrophages raw 264.7 cell lines and Wistar albino rats, Beni-Suef University Journal of Basic and Applied Sciences, 7 (2018) 719–723
25. Sandhiutami NMD, Moordiani M, Laksmiawati DR, Fauziah N, Maesaroh M, Widowati W. In vitro assesment of anti-inflammatory activities of coumarin and Indonesian cassia extract in RAW264.7 murine macrophage cell line. Iran J Basic Med Sci 2017; 20:99-106; <http://dx.doi.org/10.22038/ijbms.2017.8102>
26. THP-1 curcumin--Bisht, A., Dickens, M., Rutherford-Markwick, K., Thota, R., Mutukumira, A. N., & Singh, H. (2020). Chlorogenic Acid Potentiates the Anti-Inflammatory Activity of Curcumin in LPS-Stimulated THP-1 Cells. *Nutrients*, 12(9), 2706. doi:10.3390/nu12092706
27. THP-1 vanillin ---Zhao, D., Jiang, Y., Sun, J., Li, H., Huang, M., Sun, X., & Zhao, M. (2019). Elucidation of The Anti-Inflammatory Effect of Vanillin InLps-Activated THP-1 Cells. *Journal of Food Science*. doi:10.1111/1750-3841.14693
28. The Anti-Inflammatory Effect of Algae-Derived Lipid Extracts on Lipopolysaccharide (LPS)-Stimulated Human THP-1 Macrophages Ruairi C. Robertson 1,2, Freddy Guihéneuf 3, Bojlul Bahar 4, Matthias Schmid 3, Dagmar B. Stengel 3, Gerald F. Fitzgerald 2,5, R. Paul Ross 5,6 and Catherine Stanton 1,5, *Mar. Drugs* 2015, 13, 5402-5424; doi:10.3390/md13085402
29. David Izuchukwu Ugwu, Uchechukwu Christopher Okoro, Pius OnyeoziriUkoha, Astha Gupta & Sunday N. Okafor (2018) Novel anti-inflammatory and analgesic agents: synthesis, molecular docking and in vivo studies, *Journal of Enzyme Inhibition and Medicinal Chemistry*, 33:1, 405-415, DOI: 10.1080/14756366.2018.1426573
30. El Gizawy, H.A.; Boshra, S.A.; Mostafa, A.; Mahmoud, S.H.; Ismail, M.I.; Alsouk, A.A.; Taher, A.T.; Al-Karmalawy, A.A. *Pimenta dioica* (L.) Merr. Bioactive Constituents Exert Anti-SARS-CoV-2 and Anti-Inflammatory Activities: Molecular Docking and Dynamics, In Vitro, and In Vivo Studies. *Molecules* 2021, 26, 5844. <https://doi.org/10.3390/molecules26195844>
31. Prathap et al. *Bioinformation* 17(2): 363-368 (2021)
32. Rakesh Kumar, Saurabh Sharma, Swati Sood, Vijai K. Agnihotri, Virendra Singh & Bikram Singh (2014) Evaluation of several *Rosa damascena* varieties and *Rosa bourboniana* accession for essential oil content and composition in western Himalayas, *Journal of Essential Oil Research*, 26:3, 147-152, DOI: 10.1080/10412905.2013.829004
33. Sharad Srivastava, Adarsh Pratap Singh, A. K. S. Rawat, Comparative botanical and phytochemical evaluation of *Calotropis procera* Linn. and *Calotropis gigantea* Linn. Root, *Journal of Applied Pharmaceutical Science* Vol. 5 (07), pp. 041-047, July, 2015 Available online at <http://www.japsonline.com>, DOI: 10.7324/JAPS.2015.50707
34. Kiran Zahid, Maqsood Ahmed & Farah Khan (2017): Phytochemical screening, antioxidant activity, total phenolic and total flavonoid contents of seven local varieties of *Rosa indica* L., *Natural Product Research*, DOI: 10.1080/14786419.2017.1331228
35. Valiollah Hajhashemi, Alireza Ghannadiand Mohammad Hajiloo, **Analgesic and Anti-inflammatory Effects of *Rosa damascena* Hydroalcoholic Extract and its Essential Oil in Animal Models**, *Iranian Journal of Pharmaceutical Research* (2010), 9 (2): 163-168
36. Drug discovery and evaluation, Pharmacological evaluation, Second edition by H. Gerhard Vogel, Springer Publication, Page number 759.
37. Rajendran Vadivu and K.S. Lakshmi, In vitro and In vivo anti-inflammatory activity of leaves of *Symplocos cochinchinensis* (Lour) Moore ssplaurina, *A Journal of the Bangladesh Pharmacological Society (BDPS)*, 2008; 3: 121-124
38. Divya Jyothi, Marina Koland, Formulation and evaluation ofherbal anti-inflammatory gel containing *Trigonella Foenumgratum* tract, *International Journal of Pharmacy and Pharmaceutical Sciences*, Vol 8, Issue 1, 2016, 41-44





Preeti Jadeja et al.,

39. Juanjuan Cheng, Tingyun Ma, Wei Liu, Hanxue Wang, In vivo evaluation of the anti-inflammatory and analgesic activities of compound Muniziqi granule in experimental animal models, BMC Complementary and Alternative Medicine volume 16, Article number: 20 (2015)
40. Jian-HuaShang, Xiang-HaiCaiTaoFeng, Yun-LiZhao, Pharmacological evaluation of Alstoniascholaris: Anti-inflammatory and analgesic effects, Journal of Ethnopharmacology, Volume 129, Issue 2, 27 May 2010, Pages 174-181
41. Sumana Sarkhel, Evaluation of the anti-inflammatory activities of QuillajasaponariaMol. saponin extract in mice, Toxicology Reports, 3 (2016) 1–3
42. H M Arif Ullah, Sayera Zaman, FatematujJuhara, Lucky Akter, Syed Mohammed Tareq, Emranul Haque Masum and Rajib Bhattacharjee, Evaluation of antinociceptive, in-vivo & in-vitro anti-inflammatory activity of ethanolic extract of Curcuma zedoaria rhizome, BMC Complementary and Alternative Medicine 2014, 14:346.
43. Jacinthia B. Xavier-Santosa,1, Juliana Félix-Silvaa,1, Júlia G.R. Passosa, Jacyra A.S. Gomesa, Júlia M. Fernandesb, Development of an effective and safe topical anti-inflammatory gel containing Jatropha gossypifolia leaf extract: Results from a pre-clinical trial in mice, Journal of Ethnopharmacology, 227 (2018) 268–278 (%w/w)
44. Gaillkwad D.D. and Banerjee S. K, Development and evaluation of herbal gel formulation of Magnifera indica linn extract, Department of Pharmaceutical Sciences, Karpagam University, Coimbatore-641021, Tamil Nadu, India, International Journal of Research in Pharmaceutical Sciences.4(2) 260-265.
45. Rajashekar A, Subramaniam I, Govindarajan A, Ramasamy A (2017) Formulation and Evaluation of Novel Herbal Aerosol for Arthritis. J Rheumatol Arthritic Dis 2(4): 1-12.
46. Zdzisława Nowakowska, A review of anti-infective and anti-inflammatory chalcones, European Journal of Medicinal Chemistry 42 (2007) 125e137.
47. Venkata, M., R. Sripathy, D. Anjana, N. Somashekara, In Silico, In Vitro and In Vivo Assessment of Safety and Anti-inflammatory Activity of Curcumin, American Journal of Infectious Diseases 8 (1): 26-33, 2012
48. Bhaskar karmakar, Partha Talukdar, Soumendra Nath talapatra, An in silicostudy for two anti-inflammatory flavonoids of nerium oleander on proinflammatory receptors, 2019 Jan – Feb RJBPCS 5(1) page no.582, doi:10.26479/2019.0501.49
49. Happy Agarwal, Amatullah Nakara, Venkat Kumar Shanmugam, Anti-inflammatory mechanism of various metal and metal oxide nanoparticles synthesized using plant extracts: A review, Biomedicine & Pharmacotherapy 109 (2019) 2561–2572
50. Toby Lawrence, Derek A. Willoughby and Derek W. Gilroy, ANTI-INFLAMMATORY LIPID MEDIATORS AND INSIGHTS INTO THE RESOLUTION OF INFLAMMATION, NATURE REVIEWS, IMMUNOLOGY, VOLUME 2, OCTOBER 2002, 787-795.
51. Chittasupho, C.; Ditsri, S.; Singh, S.; Kanlayavattanakul, M.; Duangnin, N.; Ruksiriwanich, W.; Athikomkulchai, S. Ultraviolet Radiation Protective and Anti-Inflammatory Effects of Kaempferia galanga L. Rhizome Oil and Microemulsion: Formulation, Characterization, and Hydrogel Preparation. Gels 2022, 8, 639. <https://doi.org/10.3390/gels8100639>
52. Patel, N. A., Patel, N. J., & Patel, R. P. (2009). Design and Evaluation of Transdermal Drug Delivery System for Curcumin as an Anti-Inflammatory Drug. Drug Development and Industrial Pharmacy, 35(2), 234–242. doi:10.1080/03639040802266782
53. Yattoo, M. I., Gopalakrishnan, A., Saxena, A., Parray, O. R., Tufani, N. A., Chakraborty, S., Iqbal, H. M. N. (2018). Anti-Inflammatory Drugs and Herbs with Special Emphasis on Herbal Medicines for Countering Inflammatory Diseases and Disorders – A Review. Recent Patents on Inflammation & Allergy Drug Discovery, 12. doi:10.2174/1872213x12666180115153635





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Table. 1 Phytochemical examinations for the extracts as per the standard methods.

Class of Compound	Tests	Detection	Identification
Alkaloids	Wagner's Test	Wagner's reagent (Iodine in Potassium Iodide).	brown/reddish precipitate
	Dragendroff's Test	Dragendroff's Reagent (solution of Potassium Bismuth Iodide).	Red-Orange coloured precipitate
	Mayer's Test	Mayer's reagent (Potassium Mercuric Iodide)	yellow-coloured precipitate
	Hager's Test	Hager's reagent (saturated picric acid solution)	yellow coloured precipitate.
Carbohydrates	Molisch's Test	alcoholic α -naphthol solution	violet ring at the junction
	Benedict's test	Benedict's reagent	Orange red precipitate
	Fehling's Test	Fehling's A & B solutions	red precipitate
Glycosides	Modified Borntrager's Test	Ferric Chloride solution. Then extracted with benzene+ Ammonia	rose-pink colour
	Legal's Test	Sodium nitropruside in pyridine and sodium hydroxide.	pink to blood red colour
Saponins	Froth Test	distilled water 20ml	1 cm layer of foam
	Foam Test	2 ml of water	Foam produced persists for ten minutes
Phytosterols	Salkowski's Test	Chloroform+few drops of Conc. Sulphuric acid	Golden yellow colour
	Libermann Burchard's test	Choroform+few drops of acetic anhydride	brown ring at the junction
Phenols	Ferric Chloride Test	3-4 drops of ferric chloride solution	bluish black colour
Tannins	Gelatin Test	1% gelatin solution containing sodium chloride	White precipitate
Flavonoids	Alkaline Reagent Test	sodium hydroxide solution	yellow colour
	Lead acetate Test	lead acetate solution	yellow colour precipitate
Proteins and amino acids	Xanthoproteic Test	conc. Nitric acid.	yellow colour
	Ninhydrin Test	0.25% w/v Ninhydrin reagent	Blue colour
Diterpenes	Copper acetate Test	3-4 drops of copper acetate solution	Emerald green colour

Table. 2 Chromatographic conditions for quantification of chemical constituents in Polyherbal Gel

Chromatographic Conditions:	
Application Mode	CAMAG Linomat 5 - Applicator
Filtering System	Whatman filter paper No. 1
Stationary Phase	MERCK - TLC / HPTLC Silica gel 60 F254 on Aluminum sheets
Application (Y axis) Start Position	10 mm
Development End Position	80 mm from plate base
Standard Application Volume	10.0 μ L
Sample Application Volume	10.0 μ L
Distance Between Tracks	13.3 mm





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Development Mode	CAMAG TLC Twin Trough Chamber
Chamber Saturation Time	30 minutes
Mobile Phase (MP) for Vasicine	Dioxane: Toluene: Methanol: Ammonia (5: 2: 2: 1 v/v) at 254 nm
Mobile Phase (MP) for Gallic acid	Toluene: Ethyl acetate: Formic acid (10: 7: 1 v/v) at 275 nm
Mobile Phase (MP) for Rutin	Toluene: Ethyl acetate: Formic acid: Methanol at 257 nm
Drying Mode, Temp. & Time	TLC Plate Heater Preheated at 100 ± 5°C for 3 minutes

Table 3. Preliminary phytochemical screening was performed to find out the phytoconstituent present in the extracts.

	AVM	AVA	RIM	RIA	CPM	CPA
Alkaloids	+ve	+ve	+ve	+ve	-ve	-ve
Saponin	+ve	+ve	+ve	+ve	+ve	+ve
Carbohydrates	+ve	+ve	+ve	+ve	+ve	-ve
Phenolic glycoside/Tannins	+ve	+ve	-ve	-ve	+ve	+ve
Proteins	-ve	-ve	-ve	-ve	+ve	+ve
Flavonoids	+ve	+ve	+ve	+ve	+ve	+ve
Volatile Oil	-ve	-ve	+ve	+ve	+ve	-ve
Fixed Oil	-ve	-ve	+ve	+ve	+ve	-ve

Table 4. Results of Evaluation parameters of developed herbal gel

Evaluation parameter	Value of parameter
Appearance and Homogeneity	Brownish Transparent
pH	7.42-7.88
Viscosity	5600 cp
Spreadability	45mm
Assay (Vasicine: Gallic acid: Rutin)	0.151 %: 0.058 %: 0.031 %

Table. 5 Anti-inflammatory activity of Polyherbal formulation using carrageenan-induced paw oedema inrats.

Groups (n=6)	Inhibition of edema (%)					
	1 hr	2 hr	3 hr	4 hr	5 hr	6 hr
Carrageenan	-	-	-	-	-	-
Carrageenan+ Diclofenac Gel	60.0	63.0	62.0	65.0	61.0	59.0
Carrageenan+ Polyherbal Gel	65.0	67.0	68.0	69.0	68.0	67.0

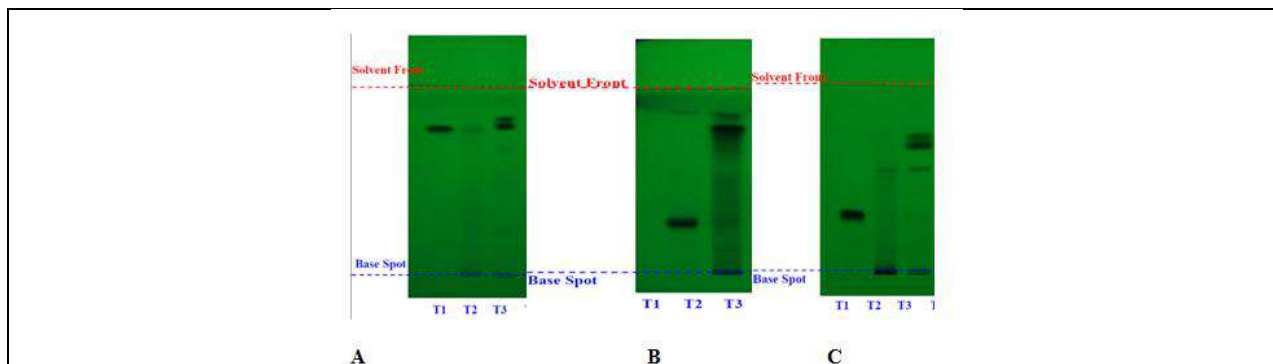


Figure. 1 HPTLC scan profile of Adhatoda vasica, Rosa indica and Calotropis procera

Fig. 1A Track T1- Standard vasicine Fig.1 C Track T1-Standard Gallic acid Track T2- Adhatoda vasica extract TrackT2- Calotropisprocera extract Track T3- Polyherbal GelTrack T3- Polyherbal Gel Fig. 1 B Track





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T1- Standard Rutin
Track T2- Rosa indica extract
Track T3- Polyherbal Gel

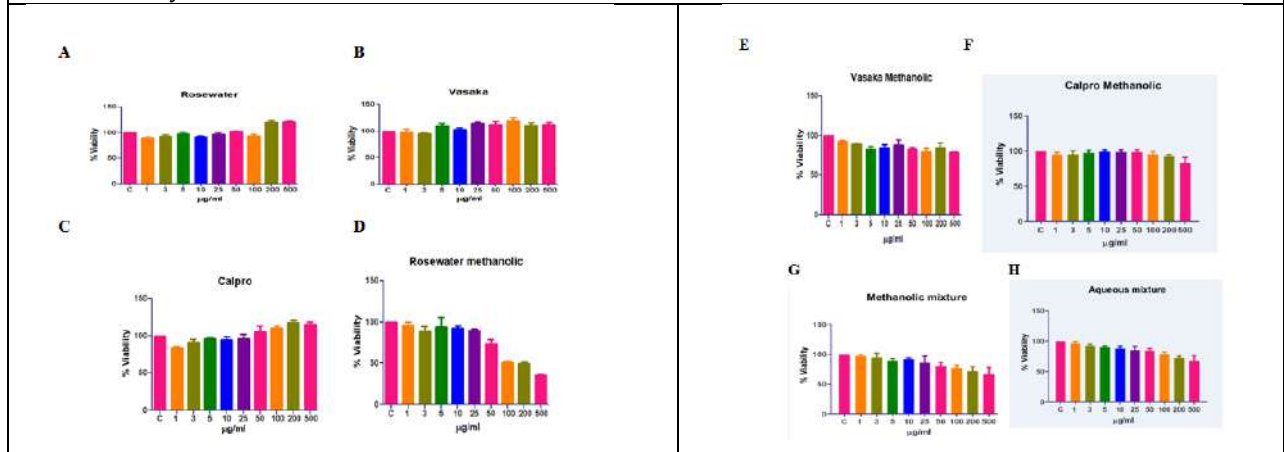


Figure. 2MTT Assay of A) Aqueous extract of *Rosa indica* B) Aqueous extract of *Adhatoda vasica* C) Aqueous extract of *Calotropis procera* D) Methanolic extract of *Rosa indica* E) Methanolic extract of *Adhatoda vasica* F) Aqueous extract of *Calotropis procera* G) Mixture of three methanolic extract H) Mixture of three aqueous extracts.

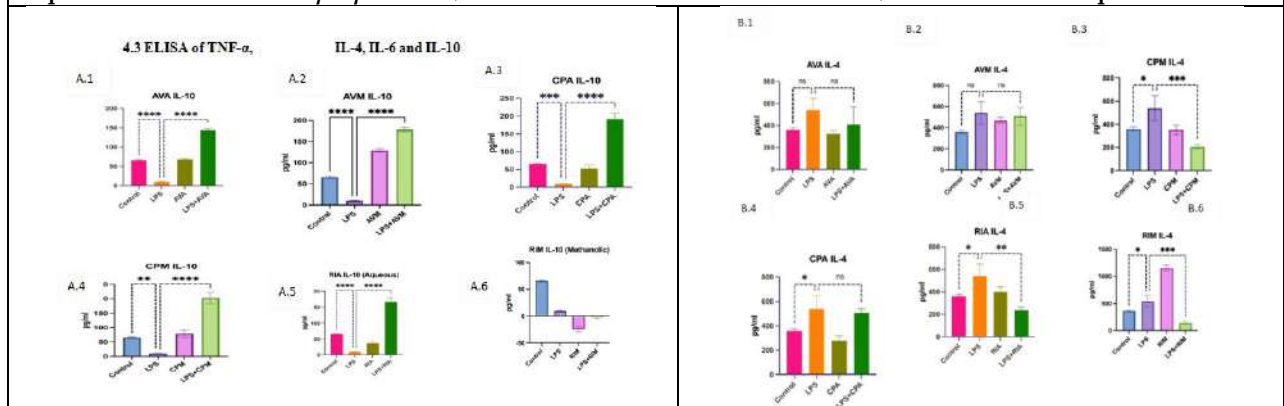
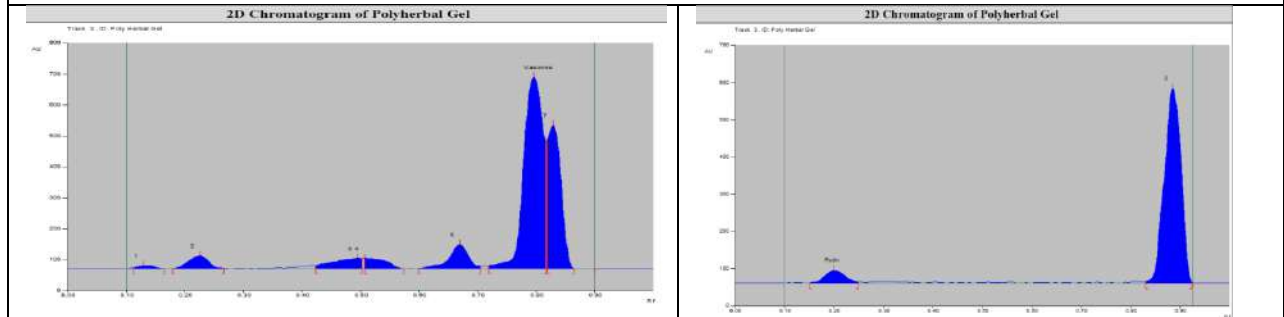


Figure 3Effect on IL-10 A.1) Aqueous extract of *Adhatoda vasica* A.2) Methanolic extract of *Adhatoda vasica* A.3) Aqueous extract of *Calotropis procera* A.4)Methanolic extract of *Calotropis procera* A.5) Aqueous extract of *Rosa indica* A.6) Methanolic extract of *Rosa indica*





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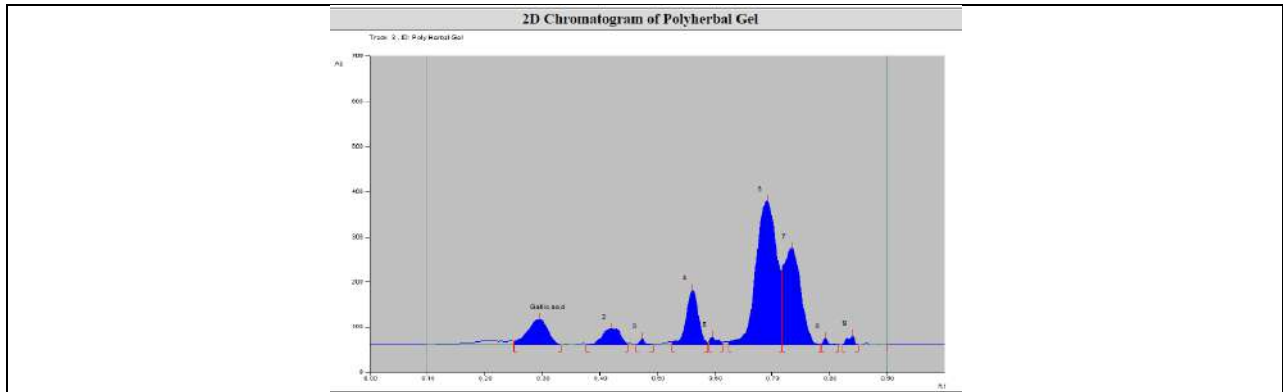


Figure. 4A)HPTLC chromatogram for vasicine in herbal Gel B) HPTLC chromatogram for Rutin in herbal Gel C) HPTLC chromatogram for Gallic acid in herbal Gel





Effect of Colloidal Nano Silica on the Properties of Natural and Recycled Aggregate Concrete

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ABSTRACT

The current study used two factorial approaches to investigate how the replacement of colloidal nano-silica affected the workability, compressive strength, split tensile strength, and flexural strength of concrete containing natural and recycled aggregate. Recycled aggregate (%), colloidal nano-silica (%), and specimen type were chosen as the three factors with two levels each in this investigation. The compressive strength at seven, 28, and 90 days was chosen as the response for three identical concrete mix samples. The experiment's results are analyzed to determine the impact of various factors, and various charts are used to display the investigation's findings. The investigation's findings demonstrated that the variables selected had a major impact on the flexural, split tensile, and compressive strengths. Nevertheless, the analysis shows that a combination of components does not significantly affect the strength of concrete.

Keywords: Colloidal Nano-silica , Natural aggregate concrete, recycled aggregate concrete.

INTRODUCTION

Worldwide, the number of construction and demolition projects is rising daily as a result of urbanization, economic expansion, and population growth [1]. Demolition of existing buildings and construction of new construction projects are referred to as construction and demolishing. Even though these operations and activities are essential to the majority of communities worldwide, they have brought up certain security and internationally acknowledged issues, such as the depletion of natural resources and ecosystem changes [2]. Large volumes of waste are produced by construction and demolition operations, which are referred to as construction & demolition waste (CDW). The yearly production of CDW is estimated to be 0.5 billion tons worldwide [3]. One of the main environmental issues



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associated with a significant amount of CDW is the use of different land areas for waste disposal and soil pollution. Researchers and the construction industry have conducted a study that has produced several ways to mitigate the impact of these worries. One useful technique is to use CDW in concrete [4]. For both fine and coarse aggregates in recycled concrete, recycled aggregate concrete is an option. By using CDW as recycled aggregate concrete, significant land areas and natural resources can be preserved, as well as our environment [5]. Several researchers have examined the potential for incorporating recycled aggregate in the construction industry for decades [6]. Despite the fact that using CDW in concrete benefits the environment in the ways outlined above, its application is limited [7, 8]. The biggest barrier to the adoption of RCA is the lower qualities of such aggregate in compared to natural aggregates. The performance of concrete containing such aggregate is also inferior to that of concrete including conventional aggregate [4, 9]. Previous research [3-5, 10, 11] showed this. Concrete made with RCA has low strength, high water absorption, high porosity, shrinkage, and creep [4, 5, 11]. The RAC content determines how much the strength of the concrete decreases. Recycled aggregate concrete (RAC) has a lower compressive strength than natural aggregate concrete (NAC) [12]. Additionally, the splitting tensile strength of the RAC is up to 25% lower [4]. Moreover, flexural strength in concrete is reduced by 30% when RCA is used [5].

MATERIALS & METHODOLOGY

The present study aims to produce cementitious composites by replacing natural concrete aggregate with 100% recycled aggregate from construction and demolition waste and colloidal nano silica. The characteristics of workability and strength are contrasted with the control mix. At first, different percentages of CNS were used to partially replace cement (0%, 0.75%, 1.5% & 3%). The mix proportions of concrete, with workability and strength in compression of 52.2 MPa, 52.96 MPa, 53.60 Mpa and 54.88 MPa were designed with NAC materials based on IS 10262:2009. Later, recycled aggregate concrete was 100 % as a replacement of NAC. A total of 24 cubes of standard size 150 × 150 × 150 mm were prepared for all grades of concrete to develop mixed concrete.

MATERIALS

Ordinary Portland cement (OPC) of grade 43 was used in this investigation. It fulfills the criteria set forth by Indian standards. Many standard preliminary tests have been carried out to ascertain the characteristics of cement. The physical characteristics of cement are listed in Table 1. There were two types of aggregate used: natural and recycled. The maximum size allowed in the aggregate is 20 mm. The colloidal nano-silica utilized in this investigation was manufactured commercially by the chemicals company. This reactive mineral admixture is a very fine white powder. The physical properties are displayed in Table 2.

Mixes, Variables, and Mix Proportioning

Recycled aggregate is used in place of natural aggregate in the concrete mix design according to the guidelines provided by the Bureau of Indian Standard (IS: 10262–2009). The concrete mixes that were prepared in detail, which included NAC0, NAC0.75, NAC1.5, and NAC3 with natural coarse aggregate and RAC0, RAC0.75, RAC1.5, and RAC3 with recycled coarse aggregate, were prepared using various doses of CNS in place of cement by weight. In the experiment, four distinct % replacements of cement by weight with CNS (i.e., 0.5%, 0.75%, 1.5%, and 3%), were taken into consideration. All of the mixtures used natural river sand that was readily available locally as Natural fine aggregate (NFA). The control mixes were designed in accordance with BIS (IS: 10262–2009) for concrete in the M25 grade. Additional modifications were implemented based on the moisture content and absorption capacity.

RESULTS

Workability

Table 3 illustrates the slump values of natural aggregate concrete. A dosage of 0% to 3% CNS reduced the slump from 68 to 55.5 mm. The formation of a structure with high water retention after the addition of CNS could account





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for this behavior. Consequently, there was less lubricating water in the mixture, which could lead to an increase in fresh concrete's viscosity and a decrease in slump. More trapped air could arise from the concrete containing of CNS notable. When natural aggregate concrete was completely replaced by recycled aggregate concrete, slump values decreased. Slump value decreases with CNS and RAC content.

Compressive Strength (CS)

Figure 2 depicts the compressive strength of concrete after 7, 28 and 90 days as a function of CNS content. The 90-day compressive strength of NAC was significantly increased by CNS addition and showed a progressive increase from 52.02 to 54.88 MPa for 0% to 3% CNS addition. After 7 days, the compressive strength increased from 41.2 to 45.60 MPa for 0% to 3% CNS addition, indicating a progressive improvement. For example, the 90-day compressive strength of RAC was reduced by CNS addition and the values increased, but the compressive strength of RAC was reduced in comparison to the NAC. The Compressive Strength test results of the samples are tabulated in Table 4.1 below.

Split tensile strength (STS)

Table 5 shows the splitting tensile strength results of cylindrical samples after 28 days of curing of mixes made with CNS in both (NAC & RAC). Figure 13 also depicts the splitting tensile values (MPa). These figures are the mean of three cylindrical samples. The trend of the splitting tensile strength results in the reference group (NAC0) is similar to the trend of the compressive strength results. The splitting tensile strength of RAC-based mixes was lower than that of the reference mix NAC. The splitting tensile strength of RAC composites decreased to 3.02, 3.40, 3.95, and 3.98 MPa, compared to 4.12 MPa for NAC mixture. According to Table 5, this indicates that the concrete lost roughly 3.5% of its strength when the NCA was substituted with the RCA at a content of 100%.

Flexural tensile strength (FTS)

For both of the above concrete mix cases, test specimens measuring 150 mm x150 mm x 700 mm were cast and tested to determine the impact of CNS on the flexural tensile strength (FTS) characteristics of concrete made with NAC with replacement of cement with CNS in the percentage of 0%, 0.75%, 1.5%, and 3% by weight at the age of 28 days. Additionally, the influence of this CNS on the concrete of above grade made with RAC in the above percentage replacement of cement with CNS and at the same age was taken into consideration. Table 6 tabulates the average values of the test results.

Comparison of Compressive strength and split tensile strength

For both NAC and RAC mixes, an interaction relation in the form of quadratic equations was derived from the experimental test results on cube CS and STS at 28 days of curing. These are displayed in Figs. 5 and 6. From Fig. 5, the interaction relationship between the STS and cube CS of concrete with NAC and with the % replacements of cement with CNS at 0%, 0.75%, 1.5%, and 3% is given by equation 1. In addition, from Fig. 6, the interaction equation for concrete of the same grade made with RAC was given by equation 2.

$$f_{sp} = 0.43964 f_c^2 - 41.28383 f_c + 972.26786 \dots\dots\dots (i)$$

$$f_{sp} = - 0.10673 f_c^2 + 9.87346 f_c - 224.31338 \dots\dots\dots (ii)$$

Comparison of Compressive strength and flexural tensile strength

Based on the available test results for the cube CS and FTS of the NAC and RAC mixes, different interaction diagrams were created for each mix, taking into account the differences in the amount of cement substituted with CNS. which are displayed in Figures 7 and 8. From Fig. 7, the interaction relationship between the FTS and cube CS of concrete with NAC and with the % replacements of cement with CNS at 0%, 0.75%, 1.5%, and 3% is given by equation 3. In addition, from Fig. 8, the interaction equation for concrete of the same grade made with RAC was given by equation 4.

$$F_f = 0.18713 f_c^2 - 17.19929 f_c + 399.93745 \dots\dots\dots (iii)$$

$$F_f = - 0.05564 f_c^2 + 5.17799 f_c - 114.86563 \dots\dots\dots (iv)$$





CONCLUSIONS

The following conclusions have been reached after variations in the constituents are identified in relation to variations in the characteristics of concrete. It has been observed that when more CNS is added in place of cement, the slump values for both the NAC and RAC mixes decrease. This may be because CNS contains unsaturated bonds that greatly increase their reactivity with water. This attraction to the CNS leads to the formation of silanol groups and chemical bonds. This will lead to a decrease in the amount of free water that can be mixed, which will increase the viscosity of the mixture and decrease its fluidity. Consequently, CNS-containing concrete mixes will be less workable. It is evident that the mechanical properties, or CS, STS, and FTS of both NAC and RAC, were significantly improved by partially replacing cement with CNS. This may be because, in the cases of both NAC and RAC mixes, a strong bond forms at the ITZ between the cement mortar and coarse aggregates. Nonetheless, NAC exhibits greater mechanical strengths than RAC across all cement replacement percentages with CNS. This could be because of internal inherent cracks that form in the RCA during the recycling process, weakening the strength characteristics in the RAC, or it could be because of inherent cracks that form in the old mortar that is adhered to the RAC. When the percentage of cement replacement with CNS varies from 0% to 3%, it is also observed from the experimental test results on mechanical characteristics that the percentage increase in CS at 28 days for NAC and RAC is found to be 3.19% and 6.42%, respectively, while the percentage increase in STS at 28 days for NAC and RAC was observed to be 32.90% and 31.78% each. At 28 days, the percentage increases in FST for NAC and RAC are 19.60% and 13.13%, respectively, in the case of FTS values. The current study's findings demonstrated that adding CNS could result in a sustainable cement-based building material with better qualities, even when the coarse aggregate was entirely recycled.

REFERENCES

1. Abbas, A., Fathifazl, G., Isgor, O. B., Razaqpur, A. G., Fournier, B., & Foo, S. (2009). Durability of recycled aggregate concrete designed with equivalent mortar volume method. *Cement & Concrete Composites*, 31(8), 555–563.
2. C.J. Zega, A.A. Di Maio(2010), Recycled concretes made with waste ready-mix concrete as coarse aggregate *Journal of Materials in Civil Engineering*, 23 (3), pp. 281-286
3. Akbarnezhad, A., Ong, K. C. G., Tam, C. T., & Zhang, M. H. (2013). Effects of the parent concrete properties and crushing procedure on the properties of coarse recycled concrete aggregates. *Journal of Materials in Civil Engineering*, 25(12), 1795–1802.
4. Buck, A. D. (1977). Recycled concrete as a source of aggregate. *ACI Journal*,74, 212–219.
5. Sagoe-Crentsil, K. K., Brown, T., & Taylor, A. H. (2001). Performance of concrete made with commercially produced coarse recycled concrete aggregate. *Cement and Concrete Research*,31, 701–712.
6. Barbudo, A.; Jiménez, J.R.; Ayuso, J.; Galvín, A.P.; Agrela, F. (2018) Catalogue of Pavements with Recycled Aggregates from Construction and Demolition Waste. *Proceedings*, 2, 1282.
7. Diotti, A.; Galvin, A.P.; Piccinalli, A.; Plizzari, G.; Sorlini, S.(2020) Chemical and Leaching Behavior of Construction and Demolition Wastes and Recycled Aggregates. *Sustainability*, 12, 326.
8. J. Thomas, N. N. Thaickavil, and P. M. Wilson,(2018) "Strength and durability of concrete containing recycled concrete aggregates," *Journal of Building Engineering*, vol. 19, pp. 349–365.
9. J. V. Puthussery, R. Kumar, and A. Garg,(2017) "Evaluation of recycled concrete aggregates for their suitability in construction activities: an experimental study," *Waste Management*, vol. 60, pp. 270–276.
10. Ozbakkaloglu, T., A. Gholampour, and T. Xie. (2017). "Mechanical and Durability Properties of Recycled Aggregate Concrete: Effect of Recycled Aggregate Properties and Content." *Journal of Materials in Civil Engineering* 30 (2): 4017275.
11. Rahal, K. (2007). "Mechanical Properties of Concrete with Recycled Coarse Aggregate." *Building and Environment* 42 (1): 407–415





Rizwan Khan et al.,

12. Zhou, C., and Z. Chen. (2017). "Mechanical Properties of Recycled Concrete Made with Different Types of Coarse Aggregate." *Construction and Building Materials* **134**:497–506.
13. Wardeh, G., E. Ghorbel, and H. Gomart. (2015). "Mix Design and Properties of Recycled Aggregate Concretes: Applicability of Eurocode 2." *International Journal of Concrete Structures and Materials* **9** (1): 1–20.
14. Akhtar, A., and A. K. Sarmah. (2018). "Construction and Demolition Waste Generation and Properties of Recycled Aggregate Concrete: A Global Perspective." *Journal of Cleaner Production* **186**:262–281.
15. Butler, L., West, J. S., and Tighe, S. L. (2013). "Effect of recycled concrete coarse aggregate from multiple sources on the hardened properties of concrete with equivalent compressive strength." *Constr. Build. Mater.*, **47**, 1292–1301.

Table 1: Properties of OPC – 43 Grade cement

Normal Consistency	Setting time (minute)		Specific gravity	Fineness modulus
	Initial	Final		
29%	90	250	3.05	2.99%

Table 2: Properties of CNS

Color	Specific gravity	Solid content	Particle size	pH
Transparent	1.20 -1.22	30.6%	10-15nm	10

Table 3: Slump value of the concrete mixes

% of CNS replacing the cement in the mix	NAC mix slump values in mm	RAC mix slump values in mm
0%	68	66
0.75%	65	54.3
1.5%	60.1	51.2
3%	55.5	50.1

Table 4: CS of NAC and RAC at 7, 28 and 90 days with different percentages of CNS

% of CNS	Compressive strength in N/mm ²					
	7 days		28 days		90 days	
	NAC	RAC	NAC	RAC	NAC	RAC
0%	41.2	38.21	47	43.12	52.02	50
0.75%	42.05	39.15	47.90	44	52.96	50.86
1.5%	44	43.10	48.10	44.95	53.60	52.10
3%	45.60	42.40	48.50	45.89	54.88	54

Table 5: STS of NAC and RAC at 28 days with different percentages of CNS

% of CNS in Concrete with replacement of Cement	28 days split tensile strength (N/mm ²)	
	NAC	RAC
0%	3.10	3.02
0.75%	3.40	3.40
1.5%	3.78	3.95
3%	4.12	3.98





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Table 6: Average FTS of concrete mixtures prepared with NAC and RAC that differ in the % of cement replaced by CNS by weight in their mixtures.

% of CNS in concrete with replacement of cement	FTS at 28 days	
	NAC	RAC
0 % CNS	5.00	4.95
0.75 % CNS	5.40	5.30
1.5 % CNS	5.78	5.43
3 % CNS	5.98	5.60

Table 7: CS and STS of NAC and RAC with various percentages at 28 days of age, and replace cement by weight with CNS.

% of CNS in concrete with replacement of cement	Compressive strength (28 days)		Split tensile strength (28 days)	
	NAC	RAC	NAC	RAC
0 % CNS	47	43.12	3.10	3.02
0.75 % CNS	47.90	44	3.40	3.40
1.5 % CNS	48.10	44.95	3.78	3.95
3 % CNS	48.50	45.80	4.12	3.98

Table 8: CS and FTS of NAC and RAC with various percentages at 28 days of age, and replace cement by weight with CNS.

% of CNS in concrete with replacement of cement	Compressive strength at 28 days		Flexural tensile strength at 28 days	
	NAC	RAC	NAC	RAC
0 % CNS	47	43.12	5	4.95
0.75 % CNS	47.90	44	5.40	5.3
1.5 % CNS	48.10	44.95	5.78	5.43
3 % CNS	48.50	45.80	5.98	5.6





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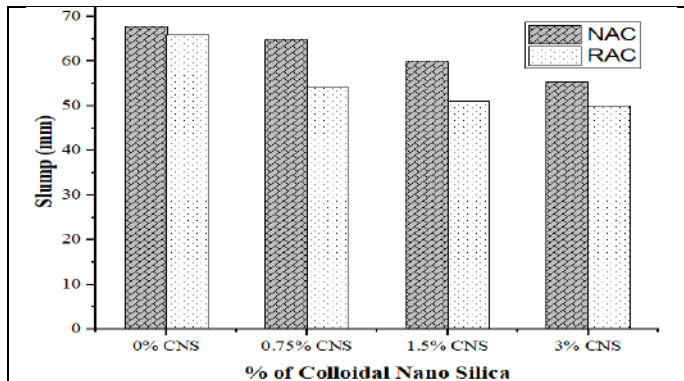


Figure 1. Slump values of NAC and RAC

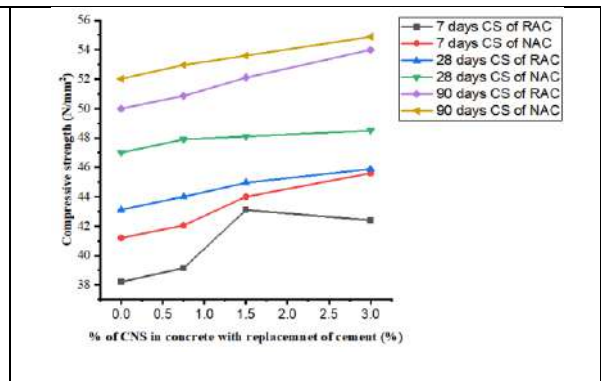


Figure 2. CS of NAC and RAC at 7, 28 and 90 days with different percentages of CNS

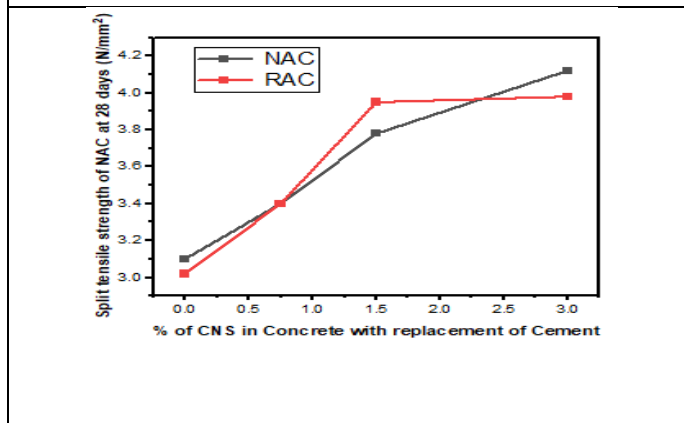


Figure 3: STS of NAC and RAC at 28 days with different percentages of CNS

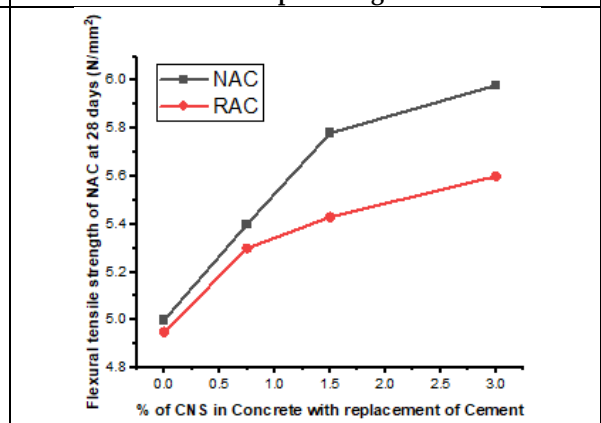


Figure 4: FST of NAC and RAC at 28 days with different percentages of CNS

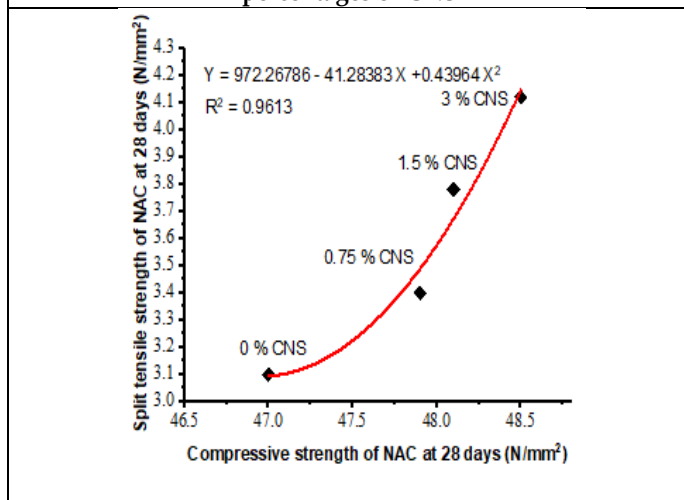


Figure 5: Comparison of CS and STS of NAC

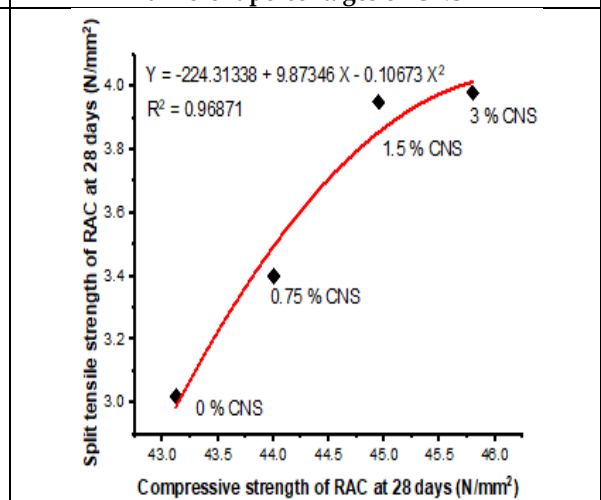


Figure 6: Comparison of CS and STS of RAC





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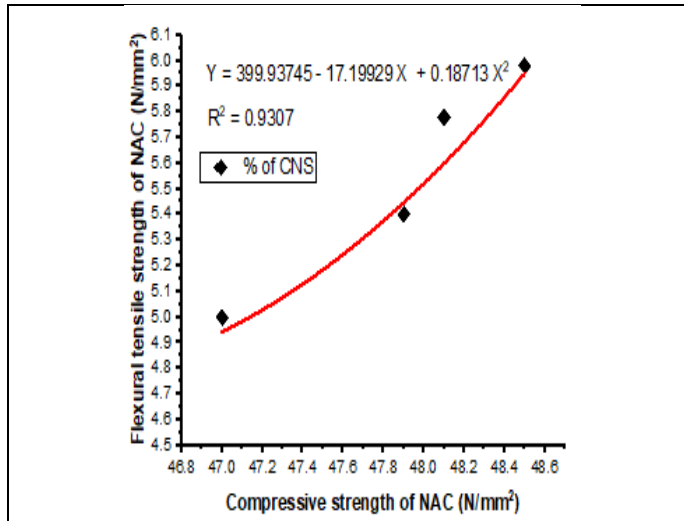


Figure 7: Comparison of CS and FTS of NAC

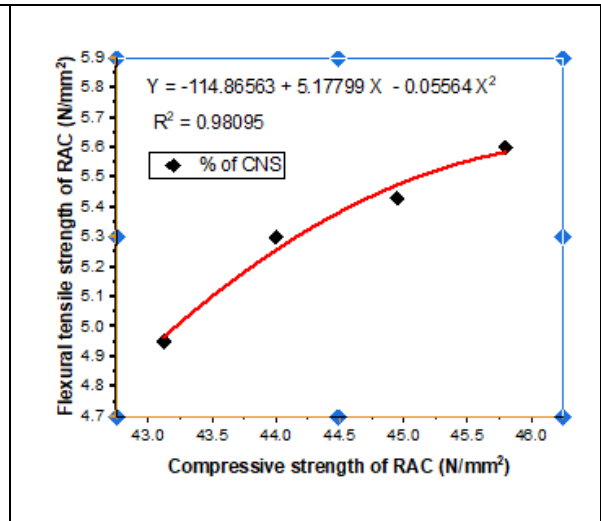


Figure 8: Comparison of CS and FTS of RAC





A Novel Approach to Solving Transportation Problems using Congruence Modulo Fermatean Fuzzy Programming with Score Functions

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ABSTRACT

Our study aims to offer a novel method for handling several conflicting features while addressing transportation problems in a Fermatean fuzzy environment. In this paper, we used the Fermatean fuzzy technique to help us turn fuzzy data into crisp data by creating a score function within the context of Fermatean nature. The authors of this study have suggested a new algorithm for solving TP utilising the congruence modulo approach, which is further illustrated with numerical examples. The obtained findings demonstrate that, in comparison to several strategies frequently used in the literature, this is one of the most effective and straightforward methods for generating an ideal solution.

Keywords: Fuzzy programming, Fermatean fuzzy (FF) programming; score function; Fermatean Fuzzy congruence modulo transportation problem.





INTRODUCTION

Transportation managers are under pressure to manage the efficient movement of goods and services in the current highly competitive market environment. The main focus of transportation challenges is figuring out how to move a product from a warehouse to a destination in the most cost-effective manner for a decision maker. As a cost-saving strategy, transportation models are widely used in supply chains and logistics. In order to solve transportation challenges, three primary parameters need to be taken into consideration, i.e.,

- a) Product available at bases
- b) Product demand at the terminus
- c) The cost of commodities per unit from i^{th} base to j^{th} point.

In order to allocate different types of products and services from multiple sources to multiple destinations, Hitchcock [1] introduced the transportation problem [TP]. A unique kind of linear programming issue, classical TP is more challenging to understand using the simplex method. As a result, many techniques have been developed in the literature to identify the first "basic feasible solution" for classical TP. The "Vogel's Method," "Column Minima Method," "North-West Corner Method," and "Matrix Minima Method" are a few of these techniques. Zadeh [2] also introduced the concept of fuzzy set theory. A membership function uses this idea of fuzzy logic to express less precise or known data mathematically. Decision-making challenges in a setting where objectives or restrictions are not clearly specified were first presented by Bellman and Zadeh [3]. Oheigeartaigh [4] created a method for moving items from supply nodes to demand nodes in a fuzzy environment and described transportation issues in actual circumstances. Chanas et al. [5] studied the topic under fuzzy uncertainty using a parametric technique to find the optimal solution for transportation challenges. Chanas and Kuchata [6] published a technique for using fuzzy parameters expressed in terms of fuzzy numbers to arrive at an optimal solution for the TP. Sahoo [7] solved TP in the FF case first in order to get the best optimum solution. *Electronics*, 12, 277, 3 (March 2023). The technique he developed next converts the FF transportation problem (FFTP) into a conventional TP. Next, Sahoo [8] projected many scoring systems for turning the fuzzy Fermatean data into a crisp form by solving the MOTP in the context of FF data using the TOPOSIS technique. Several modern methods for solving TP are studied by Ghadle et al. [9]. Ghadle et al. [10, 11, 12] developed a unique approach to modular arithmetic for the solution of TP; the same approach is then extended to solve AP, BCTP, and FrTP. Sharma [13] devises an innovative scoring mechanism to grade the fuzzy integers. A mathematical model for MOTP is built based on FF programming, which is constructed using the credibility of the FF numbers. Eight sections include this paper: First, there is an introduction and a survey of several writers' works in Section 1. The work presented in this research is broadly discussed in Section 2 of the text. A mathematical model for TP in a FF environment was developed in Section 3. We also suggested a grading scheme for FF sets in Section 4. Section 5 discusses the creation of the congruence modulo FF programming model for TP. A numerical calculation demonstrating the efficacy of our proposed method is shown in Section 6. A comparison table and comparison graphic may be found in Section 7. In Section 8, we go over the desired subject's conclusion.

Basic Definitions

Numerical procedure on Fermatean fuzzy sets (FFs)

In this case, $\tilde{f} = \langle \eta_{\tilde{f}}, \nu_{\tilde{f}} \rangle$, $\tilde{f}_1 = \langle \eta_{\tilde{f}_1}, \nu_{\tilde{f}_1} \rangle$ therefore $\tilde{f}_2 = \langle \eta_{\tilde{f}_2}, \nu_{\tilde{f}_2} \rangle$ we define arithmetic operations on the FFs as follows: let be three FFs on a universal set \mathcal{X} , and let $\lambda > 0$ be any scalar.

1. $\tilde{f}_1 \oplus \tilde{f}_2 = \langle \eta_{\tilde{f}_1}, \nu_{\tilde{f}_1} \rangle \oplus \langle \eta_{\tilde{f}_2}, \nu_{\tilde{f}_2} \rangle$
2. $\tilde{f}_1 \oplus \tilde{f}_2 = \left\langle \sqrt[3]{(\eta_{\tilde{f}_1})^3 + (\eta_{\tilde{f}_2})^3} - (\eta_{\tilde{f}_1})^3 (\eta_{\tilde{f}_2})^3, \nu_{\tilde{f}_1} \nu_{\tilde{f}_2} \right\rangle$
3. $\tilde{f}_1 \otimes \tilde{f}_2 = \langle \eta_{\tilde{f}_1}, \nu_{\tilde{f}_1} \rangle \otimes \langle \eta_{\tilde{f}_2}, \nu_{\tilde{f}_2} \rangle$
4. $\tilde{f}_1 \otimes \tilde{f}_2 = \left\langle \eta_{\tilde{f}_1} \eta_{\tilde{f}_2}, \sqrt[3]{(\nu_{\tilde{f}_1})^3 + (\nu_{\tilde{f}_2})^3} - (\nu_{\tilde{f}_1})^3 (\nu_{\tilde{f}_2})^3 \right\rangle$





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5. $\wedge \odot \tilde{f} = \langle \sqrt[3]{1 - (1 - (\eta_{\tilde{f}})^3)^{\wedge}}, (v_{\tilde{f}})^{\wedge} \rangle$
6. $\tilde{f}^{\wedge} = \langle (\eta_{\tilde{f}})^{\wedge}, \sqrt[3]{1 - (1 - (v_{\tilde{f}})^3)^{\wedge}} \rangle$
7. $\tilde{f}_1 \cup \tilde{f}_2 = \langle \max(\eta_{\tilde{f}_1}, \eta_{\tilde{f}_2}), \min(v_{\tilde{f}_1}, v_{\tilde{f}_2}) \rangle$
8. $\tilde{f}_1 \cap \tilde{f}_2 = \langle \min(\eta_{\tilde{f}_1}, \eta_{\tilde{f}_2}), \max(v_{\tilde{f}_1}, v_{\tilde{f}_2}) \rangle$
9. $\tilde{f}^c = \eta_{\tilde{f}}, v_{\tilde{f}}$.

Example

1. $\tilde{f}_1 \oplus \tilde{f}_2 = \langle 0.3, 0.5 \rangle \oplus \langle 0.4, 0.6 \rangle = \langle 0.4469, 0.3 \rangle$
2. $\tilde{f}_1 \otimes \tilde{f}_2 = \langle 0.3, 0.5 \rangle \otimes \langle 0.4, 0.6 \rangle = \langle 0.12, 0.6797 \rangle$
3. $\wedge \odot \tilde{f} = 3 \odot \langle 0.7, 0.8 \rangle = \langle 0.8948, 0.512 \rangle$
4. $\tilde{f}^{\wedge} = \langle 0.7, 0.8 \rangle^3 = \langle 0.343, 0.9597 \rangle$
5. $\tilde{f}_1 \cup \tilde{f}_2 = \langle 0.3, 0.5 \rangle \cup \langle 0.4, 0.6 \rangle = \langle 0.4, 0.5 \rangle$
6. $\tilde{f}_1 \cap \tilde{f}_2 = \langle 0.3, 0.5 \rangle \cap \langle 0.4, 0.6 \rangle = \langle 0.3, 0.6 \rangle$
7. $\tilde{f}^c = \langle 0.7, 0.8 \rangle^c = \langle 0.8, 0.7 \rangle$

The function of score

The score function of \tilde{f} represented by $S_f(\tilde{f})$ and defined as follows, may be expressed as follows if \tilde{f} is a FFs with the formula $\tilde{f} = \langle \varepsilon_f, \vartheta_f \rangle$

$$S_f(\tilde{f}) = (\varepsilon_f^3, \vartheta_f^3)$$

Property

Imagine about a hypothetical FFS $\tilde{F} = \langle \varepsilon_F, \vartheta_F \rangle$, then $S_F^*(\tilde{F}) \in [0,1]$

Proof

According to which an ortho pair is defined as, $\varepsilon_f, \vartheta_f \in [0, 1]$.

Then, $\min(\varepsilon_f, \vartheta_f) \in [0,1]$.

$$\begin{aligned} \text{Also, } \varepsilon_f^3 \geq 0, \vartheta_f^3 \geq 0, \quad \varepsilon_f^3 \leq 1 \text{ and } \vartheta_f^3 \leq 1 \\ \Rightarrow 1 - \vartheta_f^3 \geq 0 \\ \Rightarrow 1 + \varepsilon_f^3 - \vartheta_f^3 \geq 0 \end{aligned}$$

$$\therefore \frac{1}{2}(1 + \varepsilon_f^3 - \vartheta_f^3) \cdot (\min(\varepsilon_f, \vartheta_f)) \geq 0$$

Again, $\varepsilon_f^3 - \vartheta_f^3 \leq 1 \Rightarrow 1 + \varepsilon_f^3 - \vartheta_f^3 \leq 2 (\because \varepsilon_f^3 \geq 0)$

$$\Rightarrow \frac{1 + \varepsilon_f^3 - \vartheta_f^3}{2} \leq 1$$

$$\Rightarrow \frac{1}{2}(1 + \varepsilon_f^3 - \vartheta_f^3) \cdot (\min(\varepsilon_f, \vartheta_f)) \leq 1 (\because \min(\varepsilon_f, \vartheta_f) \leq 1)$$

Hence, $S_f(\tilde{F}) \in [0,1]$.

The accuracy function

If we consider \tilde{f} to be a FFs with $\tilde{f} = \langle \eta_{\tilde{f}}, v_{\tilde{f}} \rangle$, the accuracy function of \tilde{f} , represented by $\hat{A}_f(\tilde{f})$, has the following definition:

$$\hat{A}_f(\tilde{f}) = (\eta_{\tilde{f}}^3, v_{\tilde{f}}^3)$$





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Simulating a transportation problem mathematically in a Fermatean fuzzy environment

Let's look at a TP that has n demand nodes and m supply nodes. In addition, the i^{th} supply node has $p_i^f = \langle \eta_{p_i}, v_{p_i} \rangle$ units available and the j^{th} demand has $q_j^f = \langle \eta_{q_j}, v_{q_j} \rangle$ units demanded. Assume that the unit Fermatean fuzzy transportation cost from the i^{th} source node to the j^{th} demand node is $c_{ij}^f = \langle \eta_{c_{ij}}, v_{c_{ij}} \rangle$ and that the number of items carried from the i^{th} source to the j^{th} demand node is ζ_{ij} . The TP in the FF environment has the following mathematical expression:

$$\text{Minimum } F = \sum_{i=1}^m \sum_{j=1}^n c_{ij}^f \omega_{ij}, \mathcal{K} = 1, 2, 3, 4 \dots k$$

$$\text{Subject to } \sum_{j=1}^n \omega_{ij} \leq p_i^f, i = 1, 2, 3, \dots, m$$

$$\sum_{i=1}^m \omega_{ij} \geq q_j^f, j = 1, 2, 3, \dots, n$$

$$\text{Such that } p_i^f = \langle \eta_{p_i}, v_{p_i} \rangle \text{ where } 0 \leq (\eta_{p_i})^3 + (v_{p_i})^3 \leq 1,$$

$$q_j^f = \langle \eta_{q_j}, v_{q_j} \rangle \text{ Where } 0 \leq (\eta_{q_j})^3 + (v_{q_j})^3 \leq 1$$

$$c_{ij}^f = \langle \eta_{c_{ij}}, v_{c_{ij}} \rangle$$

$$\text{Where } 0 \leq (\eta_{c_{ij}})^3 + (v_{c_{ij}})^3 \leq 1, \omega_{ij} \geq 0, \forall i, j.$$

Functions of Fermatean Fuzzy Scores

Let $\tilde{f} = \langle \eta_{\tilde{f}}, v_{\tilde{f}} \rangle$ be any fuzzy Fermatean number, followed by the scoring function of \tilde{f} which is denoted by $S(\tilde{f})$, described as follow

$$S(\tilde{f}) = \frac{1}{2} (1 + \eta_{\tilde{f}} - v_{\tilde{f}}) (\min(\eta_{\tilde{f}}, v_{\tilde{f}}))^2$$

Property

Let $\tilde{f} = \langle \eta_{\tilde{f}}, v_{\tilde{f}} \rangle$ be any fuzzy Fermatean set, in which case the scoring function of $\tilde{f}, S(\tilde{f}) \in [0, 1]$.

Proof

Using the membership and non-membership pairing descriptions,

$$\eta_{\tilde{f}}, v_{\tilde{f}} \in [0, 1].$$

$$\text{Then, } \min(\eta_{\tilde{f}}, v_{\tilde{f}}) \in [0, 1].$$

$$\text{Additionally, } \eta_{\tilde{f}} \geq 0, v_{\tilde{f}} \geq 0, \eta_{\tilde{f}} \leq 1 \text{ and } v_{\tilde{f}} \leq 1 \Rightarrow 1 - v_{\tilde{f}} \geq 0 \Rightarrow 1 + \eta_{\tilde{f}} - v_{\tilde{f}} \geq 0 \therefore \frac{1}{2} (1 + \eta_{\tilde{f}} - v_{\tilde{f}}) (\min(\eta_{\tilde{f}}, v_{\tilde{f}}))^2 \geq 0,$$

$$\text{Hence, } S(\tilde{f}) \geq 0.$$

$$\text{again, } \eta_{\tilde{f}} \leq 1 \text{ and } v_{\tilde{f}} \leq 1 \Rightarrow \eta_{\tilde{f}} - v_{\tilde{f}} \leq 1$$

$$\Rightarrow 1 + \eta_{\tilde{f}} - v_{\tilde{f}} \leq 1 + 1 = 2 \Rightarrow \frac{1 + \eta_{\tilde{f}} - v_{\tilde{f}}}{2} \leq 1 \text{ and } \min(\eta_{\tilde{f}}, v_{\tilde{f}}) \leq 1 \Rightarrow (\min(\eta_{\tilde{f}}, v_{\tilde{f}}))^2 \leq 1,$$

$$\Rightarrow \frac{1}{2} (1 + \eta_{\tilde{f}} - v_{\tilde{f}}) (\min(\eta_{\tilde{f}}, v_{\tilde{f}}))^2 \leq 1,$$

$$\text{Hence, } S(\tilde{f}) \leq 1 \Rightarrow S(\tilde{f}) \in [0, 1].$$

The Congruence modulo Fermatean Fuzzy Programming methodology model that has been suggested

Transportation problem mathematical simulation in a FF environment:

Step 1: Initially, let us examine a TP in FF uncertainty, like this:

$$\text{Min } F = \sum_{i=1}^m \sum_{j=1}^n c_{ij}^f \omega_{ij}, \mathcal{K} = 1, 2, 3, 4 \dots k$$

$$\text{S.T } \sum_{j=1}^n \omega_{ij} \leq p_i^f, i = 1, 2, 3, \dots, m$$





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$$\sum_{i=1}^m w_{ij} \geq q_j^f, j = 1, 2, 3, \dots, n$$

Such that $p_i^f = \langle \eta_{\tilde{p}_i}, v_{\tilde{p}_i} \rangle$ where $0 \leq (\eta_{\tilde{p}_i})^3 + (v_{\tilde{p}_i})^3 \leq 1$,

$$q_j^f = \langle \eta_{\tilde{q}_j}, v_{\tilde{q}_j} \rangle$$
 Where $0 \leq (\eta_{\tilde{q}_j})^3 + (v_{\tilde{q}_j})^3 \leq 1$,
$$c_{ij}^f = \langle \eta_{\tilde{c}_{ij}}, v_{\tilde{c}_{ij}} \rangle$$
 Where $0 \leq (\eta_{\tilde{c}_{ij}})^3 + (v_{\tilde{c}_{ij}})^3 \leq 1$

$$w_{ij} \geq 0, \forall i, j$$

Step 2: Next, use the suggested scoring algorithm for FF sets as follows to transform converting FF data into crisp data

$$\text{Min } F = \sum_{i=1}^m \sum_{j=1}^n S(c_{ij}^f) w_{ij}, K = 1, 2, 3, 4 \dots k$$

$$\text{S. T. } \sum_{j=1}^n w_{ij} \leq S(p_i^f), i = 1, 2, 3, \dots, m$$

$$\sum_{i=1}^m w_{ij} \geq S(q_j^f), j = 1, 2, 3, \dots, n$$

Step 3: Proceed to solve this problem using the Congruence Modulo Method as follows:

- a. Examine to determine if the transportation problem is balanced.
- b. If it is balanced, this indicates that the total supply and demand are equal.
- c. If it is unbalanced, which indicates that the total supply and total demand are not equal, add dummy rows and/or dummy columns at no cost to generate a balanced one.
- d. Find the penalty in each row or column, it is the variation between the cost that is offered at the lowest and next highest levels; if there are two lowest prices, there is no penalty.
- e. Choose the maximum quantity entry amount within that penalty. The congruence mod P of each table entry should be determined to create the allocation table, which should then be represented as $(r_s)^{(q_s)}$ where (r_s) is the remainder and (q_s) is the quotient mod P.
- f. The goal of the minimization (maximization) problem is to find the row or column with the largest (smallest) penalty (P) and then, by quotient 0, 1, 2... assign resources to the cell with the lowest (highest) cost in the selected row or column. Select the lowest or maximum value by comparing the residual if the quotient of two entries is the same. If two or more penalties are equal, select the penalty with the lowest (highest) unit cost determined in that row or column.
- g. Until all supply and demand have been met or exhausted, carry on with the preceding steps.
- h. To determine whether there are $m + n - 1$ allocations.

Step 4: After using the aforementioned congruence modulo approach to solve the problem, we have a basic, feasible solution.

Computational Calculations

We examine a TP in FF uncertainty, where each variable in the problem is a FF number. This is what it looks like:

First illustration

Step 1: Now, use the score function to transform FF parameters into crisp form as follows:

Supply:

$$S(p_{f_1}) = S(\langle 0.6, 0.4 \rangle) = \frac{1}{2}(1 + 0.6 - 0.4)(\min(0.6, 0.4))^2$$

$$= \frac{1}{2}(1.2)(0.4)^2 = 0.6 \times 0.16 = 0.096$$

$$S(p_{f_2}) = S(\langle 0.3, 0.5 \rangle) = \frac{1}{2}(1 + 0.3 - 0.5)(\min(0.3, 0.5))^2$$

$$= \frac{1}{2}(0.8)(0.3)^2 = 0.4 \times 0.09 = 0.036$$

$$S(p_{f_3}) = S(\langle 0.4, 0.8 \rangle) = \frac{1}{2}(1 + 0.4 - 0.8)(\min(0.4, 0.8))^2$$





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$$= \frac{1}{2}(0.6)(0.4)^2 = 0.3 \times 0.16 = 0.048$$

Demand:

$$S(q_{f_1}) = S(\langle 0.2, 0.5 \rangle) = \frac{1}{2}(1 + 0.2 - 0.5)(\min(0.2, 0.5))^2$$

$$= \frac{1}{2}(0.7)(0.2)^2 = 0.35 \times 0.04 = 0.014$$

$$S(q_{f_2}) = S(\langle 0.4, 0.7 \rangle) = \frac{1}{2}(1 + 0.4 - 0.7)(\min(0.4, 0.7))^2$$

$$= \frac{1}{2}(0.7)(0.4)^2 = 0.35 \times 0.16 = 0.056$$

$$S(q_{f_3}) = S(\langle 0.6, 0.4 \rangle) = \frac{1}{2}(1 + 0.6 - 0.4)(\min(0.6, 0.4))^2$$

$$= \frac{1}{2}(1.2)(0.4)^2 = 0.6 \times 0.16 = 0.096$$

$$S(q_{f_4}) = S(\langle 0.2, 0.5 \rangle) = \frac{1}{2}(1 + 0.2 - 0.5)(\min(0.2, 0.5))^2$$

$$= \frac{1}{2}(0.7)(0.2)^2 = 0.35 \times 0.04 = 0.014$$

Costs:

$$S(c_{f_{11}}) = 0.018, \quad S(c_{f_{12}}) = 0.162 \dots\dots S(c_{f_{34}}) = 0.008$$

Step 2: Verify the balance of the provided transportation problem.

$$\sum_{i=1}^m S(p_{f_i}) = \sum_{j=1}^n S(q_{f_j}) \text{ Indicates that the transportation problem is balanced.}$$

Step3: Use the Congruence modulo approach to solve this problem.

$$F(w) = 0.018w_{11} + 0.16w_{12} + 0.027w_{13} + 0.1375w_{14} + 0.008w_{21} + 0.006w_{22} + 0.162w_{23} + 0.056w_{24} + 0.112w_{31} + 0.027w_{32} + 0.014w_{33} + 0.008w_{34}.$$

Subject to the constraints:

- $w_{11} + w_{12} + w_{13} + w_{14} \leq 0.096,$
- $w_{21} + w_{22} + w_{23} + w_{24} \leq 0.036,$
- $w_{31} + w_{32} + w_{33} + w_{34} \leq 0.048,$
- $w_{11} + w_{21} + w_{31} \geq 0.014,$
- $w_{12} + w_{22} + w_{32} \geq 0.056,$
- $w_{13} + w_{23} + w_{33} \geq 0.096,$
- $w_{14} + w_{24} + w_{34} \geq 0.014,$
- $w_{ij} \geq 0$

$$\sum_{i=1}^m p_i = \sum_{j=1}^n q_j .$$

The ideal solution that results from resolving this issue is as follows:

$$F = 0.00353, \quad w_{11} = 0.014, \quad w_{12} = 0, \quad w_{13} = 0.082, \quad w_{14} = 0, \quad w_{21} = 0, \quad w_{22} = 0.036, \quad w_{23} = 0, \quad w_{24} = 0, \quad w_{31} = 0, \quad w_{32} = 0.02, \quad w_{33} = 0.014, \quad w_{34} = 0.014.$$

Second illustration

Step 1: Now, use the score function to transform FF parameters into crisp form as follows:

Supply:

$$S(p_{f_1}) = S(\langle 0.2, 0.3 \rangle) = \frac{1}{2}(1 + 0.2 - 0.3)(\min(0.2, 0.3))^2$$

$$= \frac{1}{2}(0.9)(0.2)^2 = 0.45 \times 0.04 = 0.018$$

$$S(p_{f_2}) = S(\langle 0.4, 0.5 \rangle) = \frac{1}{2}(1 + 0.4 - 0.5)(\min(0.4, 0.5))^2$$





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$$= \frac{1}{2}(0.9)(0.4)^2 = 0.45 \times 0.16 = 0.072$$

$$S(p_{f_3}) = S(\langle 0.6, 0.9 \rangle) = \frac{1}{2}(1 + 0.6 - 0.9)(\min(0.6, 0.9))^2$$

$$= \frac{1}{2}(0.7)(0.6)^2 = 0.35 \times 0.36 = 0.126$$

Demand:

$$S(q_{f_1}) = S(\langle 0.9, 0.8 \rangle) = \frac{1}{2}(1 + 0.9 - 0.8)(\min(0.9, 0.8))^2$$

$$= \frac{1}{2}(1.1)(0.8)^2 = 0.55 \times 0.64 = 0.352$$

$$S(q_{f_2}) = S(\langle 0.7, 0.6 \rangle) = \frac{1}{2}(1 + 0.7 - 0.6)(\min(0.7, 0.6))^2$$

$$= \frac{1}{2}(1.1)(0.6)^2 = 0.55 \times 0.36 = 0.198$$

$$S(q_{f_3}) = S(\langle 0.6, 0.2 \rangle) = \frac{1}{2}(1 + 0.6 - 0.2)(\min(0.6, 0.2))^2$$

$$= \frac{1}{2}(1.4)(0.2)^2 = 0.7 \times 0.04 = 0.028$$

$$S(q_{f_4}) = S(\langle 0.2, 0.3 \rangle) = \frac{1}{2}(1 + 0.2 - 0.3)(\min(0.2, 0.3))^2$$

$$= \frac{1}{2}(0.9)(0.2)^2 = 0.45 \times 0.04 = 0.018$$

Costs:

$$S(c_{f_{11}}) = 0.063, S(c_{f_{12}}) = 0.016$$

$$S(c_{f_{13}}) = 0.036, S(c_{f_{14}}) = 0.04$$

$$S(c_{f_{21}}) = 0.0075, S(c_{f_{22}}) = 0.03$$

$$S(c_{23}) = 0.034, S(c_{f_{24}}) = 0.014$$

$$S(c_{f_{31}}) = 0.0875, S(c_{f_{32}}) = 0.1625$$

$$S(c_{f_{33}}) = 0.096, S(c_{f_{34}}) = 0.234$$

Step 2: Verify the balance of the provided transportation problem. If not, create balanced one by adding dummy rows or columns.

$$\sum_{i=1}^m S(p_{f_i}) = \sum_{j=1}^n S(q_{f_j}) \text{ Indicates that the transportation problem is balanced.}$$

Step3: Use the Congruence modulo approach to solve this problem.

$$F(w) = 0.063w_{11} + 0.016w_{12} + 0.036w_{13} + 0.04w_{14} + 0.0075w_{21} + 0.03w_{22} + 0.034w_{23} + 0.014w_{24} + 0.0875w_{31} + 0.1625w_{32} + 0.096w_{33} + 0.234w_{34} + 0w_{41} + 0w_{42} + 0w_{43} + 0w_{44}.$$

Subject to the constraints:

$$w_{11} + w_{12} + w_{13} + w_{14} \leq 0.018,$$

$$w_{21} + w_{22} + w_{23} + w_{24} \leq 0.072,$$

$$w_{31} + w_{32} + w_{33} + w_{34} \leq 0.126,$$

$$w_{41} + w_{42} + w_{43} + w_{44} \leq 0.380,$$

$$w_{11} + w_{21} + w_{31} + w_{41} \geq 0.352,$$

$$w_{12} + w_{22} + w_{32} + w_{42} \geq 0.198,$$

$$w_{13} + w_{23} + w_{33} + w_{43} \leq 0.028,$$

$$w_{14} + w_{24} + w_{34} + w_{44} \leq 0.018,$$

$$w_{ij} \geq 0,$$

$$\sum_{i=1}^m p_i = \sum_{j=1}^n q_j.$$

After solving this problem, we obtain the optimal solution as follows:





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$F = 0.011853$, $w_{11} = 0$, $w_{12} = 0.018$, $w_{13} = 0$, $w = 0$, $w_{21} = 0.072$, $w_{22} = 0$, $w_{23} = 0$, $w_{24} = 0$, $w_{31} = 0.126$, $w_{32} = 0$, $w_{33} = 0$, $w_{34} = 0$, $w_{41} = 0.154$, $w_{42} = 0.18$, $w_{43} = 0.028$, $w_{44} = 0.018$.

CONCLUSION

Extended fuzzy data, such as intuitionistic data, Pythagorean data, Fermatean data, and other uncertain data, can be extended using a variety of methodology. There are also several ways to turn fuzzy data into crisp data. In order to help manage Fermatean fuzzy (FF) uncertainty in objective information, this study proposes a scoring function that scores FF numbers. Next, we provide congruence modulo FF programming techniques for transportation problems with uncertainty. A non-linear programming technique called FF programming is used to address transportation-related issues. The application of Pythagorean fuzzy programming is extended. In the FF framework, we solved a numerical example of a TP by building a TP model and applying the proposed Congruence Modulo FF programming approach. We determined that our recommended approach is effective for finding the optimal compromise for problems pertaining to transportation. As a result, we can say that our method offers a way to deal with transportation issues in the FF environment and that the FF programming strategy we've suggested can be applied to any other fuzzy environment.

REFERENCES

1. Hitchcock, F.L. The distribution of a product from several sources to numerous localities. *J. Math. Phys.* 1941, 224–230. <https://www.scirp.org/reference/referencespapers?referenceid=1770622>
2. Zadeh, L.A. Fuzzy sets. *Inf. Control* 1965, 8, 338–353. <https://www.scirp.org/reference/ReferencesPapers?ReferenceID=1235352>
3. Bellman, R.E.; Zadeh, L.A. Decision making in a fuzzy environment. *Manag. Sci.* 1970, 17, 141–164. <https://ayouty.com/4AI/DECISION-MAKING%20IN%20A%20FUZZY%20ENVIRONMENT.pdf>
4. Oheigearthaigh, M. A fuzzy transportation algorithm. *Fuzzy Sets Syst.* 1982, 8, 235–243. <https://www.sciencedirect.com/science/article/pii/0165011484900575>
5. Chanas, S.; Kolodziejczyk, W.; Machaj, A. A fuzzy approach to the transportation problem. *Fuzzy Sets Syst.* 1984, 13, 211–221. <https://www.sciencedirect.com/science/article/pii/0165011484900575>
6. Chanas, S.; Kuchata, D. A concept of the optimal solution of the transportation problem with fuzzy cost coefficients. *Fuzzy Sets Syst.* 1996, 82, 299–305. <https://www.sciencedirect.com/science/article/pii/0165011495002782>
7. Sahoo, L. A new score function based Fermatean fuzzy transportation problem. *Results. Control Optim.* 2021, 4, 100040. <https://www.sciencedirect.com/science/article/pii/S2666720721000242>
8. Sahoo, L. Some score functions on Fermatean fuzzy sets and its application to bride selection based on TOPSIS method. *Int. J. Fuzzy Syst. Appl.* 2021, 10, 18–29. <https://www.igi-global.com/article/some-score-functions-on-fermatean-fuzzy-sets-and-its-application-to-bride-selection-based-on-topsis-method/280534>
9. K. Ghadle and D. Munot, Recent advances on reliable methods for solving Transportation Problem and Fuzzy Transportation Problem, *Asian Journal of Mathematics and computer research*, 26(2), 2019,95107. https://www.researchgate.net/publication/334823988_RECENT_ADVANCES_ON_RELIABLE_METHODS_FOR_SOLVING_TRANSPORTATION_PROBLEM_AND_FUZZY_TRANSPORTATION_PROBLEM
10. K. Ghadle and D. Munot, A new approach to solve assignment problem using congruence modulo and its coding in MATLAB, *Advances in Mathematics: Scientific Journal*, 9(11), 2020,9551-9557. https://www.researchgate.net/profile/Kirtiwant-Ghadle/publication/346017803_A_NEW_APPROACH_TO_SOLVE_ASSIGNMENT_PROBLEM_USING_CONGRUENCE_MODULO_AND_ITS_CODING_IN_MATLAB/links/5fb6371a299bf104cf5ae2ef/A-NEW-APPROACH-TO-SOLVE-ASSIGNMENT-PROBLEM-USING-CONGRUENCE-MODULO-AND-ITS-CODING-IN-MATLAB.pdf





Sharmila Banu and Prasanna

11. K.Ghadle and D.Munot, A freezing method for solving Bottleneck-Cost Transportation Problem, Turkish Journal of Computer and Mathematics Education, 12(14), 2021,3551-3556.https://www.researchgate.net/publication/354671854_A_Freezing_Method_for_Solving_Bottleneck-Cost_Transportation_Problem
12. Dhanashri A. Munot and Kirtiwant P. Ghadle, A novel way for solving fractional transportation problem, April 2023.https://www.mililink.com/upload/article/2117936917aams_vol_226_april_2023_a17_p1243-1251_dhanashri_a._munot_and_kirtiwant_p._ghadle.pdf
13. Sharma, M.K.; Kamini; Dhaka, A.; Nandal, A.; Rosales, H.G.; Monteagudo, F.E.L.; Hernández, A.G.; Hoang, V.T. Fermatean Fuzzy Programming with New Score Function: A New Methodology to Multi-Objective Transportation Problems. <https://www.mdpi.com/2079-9292/12/2/277>

Table 1

	D₁	D₂	D₃	D₄	Supply
A	(0.2, 0.3)	(0.6,0.7)	(0.3,0.7)	(0.6,0.5)	(0.6,0.4)
B	(0.7,0.1)	(0.2,0.9)	(0.6,0.7)	(0.4,0.7)	(0.3,0.5)
C	(0.8, 0.4)	(0.3, 0.7)	(0.2, 0.5)	(0.7, 0.1)	(0.4, 0.8)
Demand	(0.2, 0.5)	(0.4, 0.7)	(0.6, 0.4)	(0.2, 0.5)	

Table 2

	D₁	D₂	D₃	D₄	Supply
A	0.018	0.162	0.027	0.1375	0.096
B	0.008	0.006	0.162	0.056	0.036
C	0.112	0.027	0.014	0.008	0.048
Demand	0.014	0.056	0.096	0.014	0.18

Table 3

	D₁	D₂	D₃	D₄	Supply
A	0.018^0	0.018^3	0.027^0	0.045^2	0.096
B	0.008^0	0.006^0	0.018^3	0.008^1	0.036
C	0.016^2	0.027^0	0.014^0	0.008^0	0.048
Demand	0.014	0.056	0.096	0.014	

Table 4

	D₁	D₂	D₃	D₄	Supply
A	(0.7, 0.3)	(0.2, 0.4)	(0.3, 0.5)	(0.4, 0.9)	(0.2, 0.3)
B	(0.6, 0.1)	(0.7, 0.2)	(0.9, 0.2)	(0.2, 0.5)	(0.4, 0.5)
C	(0.5, 0.8)	(0.8, 0.5)	(0.6, 0.4)	(0.9, 0.6)	(0.6, 0.9)
Demand	(0.9, 0.8)	(0.7, 0.6)	(0.6, 0.2)	(0.2, 0.3)	

Table 5

	D₁	D₂	D₃	D₄	Supply
A	0.063	0.016	0.036	0.04	0.018
B	0.0075	0.03	0.034	0.014	0.072
C	0.0875	0.1625	0.096	0.234	0.126
D	0	0	0	0	0.380
Demand	0.352	0.198	0.028	0.018	0.596

Table 6





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	D ₁	D ₂	D ₃	D ₄	Supply
A	0.029 ⁰	0.016 ⁰	0.002 ¹	0.006 ¹	0.018
B	0.0075 ⁰	0.03 ⁰	0 ¹	0.014 ⁰	0.072
C	0.0195 ²	0.0265 ⁴	0.028 ²	0.03 ⁶	0.126
	0 ⁰	0 ⁰	0 ⁰	0 ⁰	0.380
Demand	0.352	0.198	0.028	0.018	

Table 7

Example Number	NWCM	LCM	Proposed method	MODI method
1.	0.016446	0.00597	0.00353	0.00353
2.	0.012699	0.011853	0.011853	0.011853

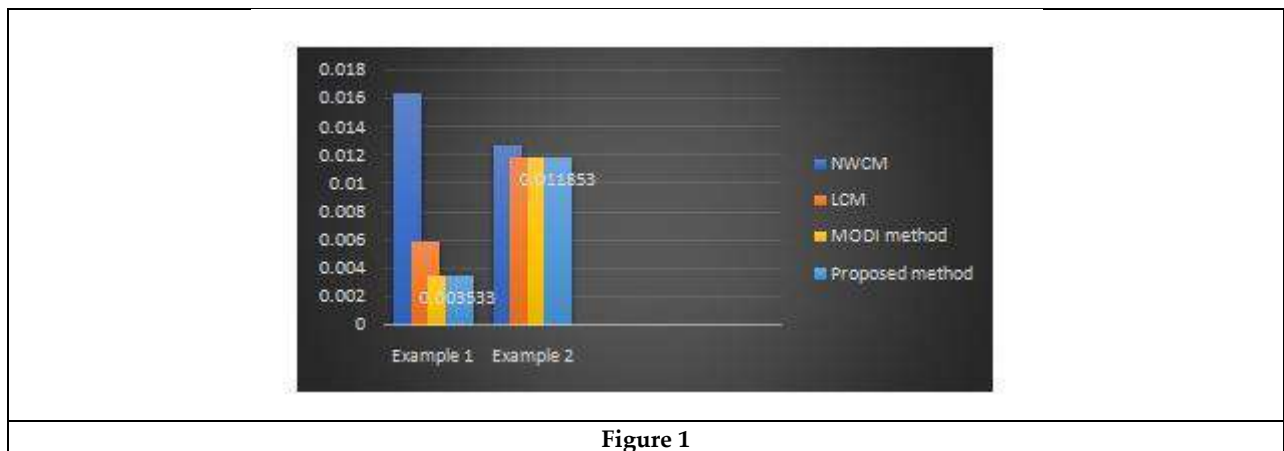


Figure 1





A Cloud Load Balancing Algorithm Considering Processor Capacity, Memory Capacity, Storage Capacity and Network Congestion

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ABSTRACT

This study offers a novel load balancing method designed to meet the unique requirements of contemporary cloud computing infrastructures. The technique determines individual server weights to optimize job allocation by incorporating a thorough assessment of server attributes such as network congestion, processor capability, storage capacity, and runtime memory. The method efficiently reduces problems such as server overload and improves system performance by using efficient work dispatching based on these computed weights. Because the method can adapt to different workload circumstances and network constraints, it can be used in a wide range of real-world cloud computing environments. By addressing the basic flaws in current methods, this novel approach to load balancing provides a well-rounded solution for maximizing resource usage and system scalability in modern cloud computing environments.

Keywords: Cloud computing, load balancing, Network congestion, processor capabilities, runtime memory, storage capacity





INTRODUCTION

In the field of contemporary computing, cloud computing has become a paradigm-shifting phenomenon, providing businesses and people with unmatched resource efficiency, scalability, and flexibility. However, because cloud infrastructures work with a shared resource paradigm, there are a lot of obstacles to overcome in terms of effectively allocating and using these resources. In cloud computing systems, load balancing—the deliberate division of computational jobs among several servers to maximize resource usage and preserve system performance—is one of the most critical issues. Load balancing becomes crucial in this situation since an uneven task distribution might have negative effects like server overload, underutilized resources, and decreased system performance. Sophisticated load balancing algorithms that can manage job allocation based on workload factors and server parameters are necessary to address these difficulties. In order to handle the complexity of contemporary cloud computing settings, a unique load balancing technique is proposed in this research study. The algorithm uses important server characteristics to determine a comprehensive weight for each server, such as network congestion, processor capacity, storage capacity, and runtime memory capacity. The technique seeks to give a comprehensive evaluation of each server's capacity to manage incoming jobs by adding these factors into the weight calculation. Intelligent job dispatching, which assigns jobs to servers according to their weights, is a key component of the suggested method. The technique minimizes the risk of server overload while optimizing system performance by giving higher weights to the jobs that are allocated to servers. By distributing computational work in a way that best plays to each server's advantages, this assignment technique improves the responsiveness and scalability of the system. Moreover, the algorithm's dependence on objective parameters allows it to be flexible enough to accommodate different workload scenarios and network conditions, making it appropriate for implementation in a range of cloud computing environments. This flexibility helps the algorithm work better and is also a factor in its wider applicability in many real-world cloud computing scenarios. The innovation and value of this study lay in its innovative approach to load balancing inside cloud computing systems, which tackles numerous fundamental shortcomings of previous techniques. A crucial component of the algorithm is its extensive weight calculation approach, which takes into account several server parameters like network congestion, processor capacity, storage capacity, and runtime memory capacity. The algorithm offers a more comprehensive assessment of each server's capacity to efficiently handle incoming jobs by taking these many aspects into account. The program also presents a novel job dispatching mechanism that uses the computed weights of the jobs to intelligently send them to servers. By giving larger weights to servers, this method optimizes job distribution to reduce the possibility of server overload while enhancing system performance as a whole.

LITERATURE REVIEW

There are various cloud load balancing approaches which have been suggested by several authors. Abiodun Kazeem Moses and Sanjay Misra have proposed a new load balancing algorithm by combining the maximum-minimum and round robin algorithm[1].A. Francis Saviour_Devaraj and Mohamed Elhoseny gave a load balancing algorithm which is the hybrid of firefly and improved Multi-Objective Particle Swarm Optimization (IMPSO) technique[2].Rajeev Kumar Gupta and Rajesh Kumar Pateriya have proposed a Balance Resource Utilization approach to form a new load balancing algorithm [2]. Shang-Liang Chen and Yun-Yao Chen have proposed a new load balancing algorithm based on a dynamic annexed balance method [4].Gaochao Xu, Junjie Pang and Xiaodong Fu have proposed a load balancing algorithm based on cloud partitioning concept [5]. Fahimeh Ramezani, Jie Lu and Farookh Khadeer Hussain have proposed a Task based System Load balancing method using Particle Swarm Optimization [6]. Chetan Kumar Sean Marston have designed a load balancing algorithm based on dynamic pricing model which focuses on reducing the energy consumption of virtual Machines [7].Deepak Puthal and Mohammad S. Obaidat have proposed a new load balancing algorithm which allocates tasks to EDCs(Edge Data Centres) optimally [8].Zhao Tong and Xiaomei Deng have proposed a novel load balancing Algorithm based on deep reinforcement learning(DLR) under service-level agreement [9]. Nilayam Kumar Kamila and Jaroslav Frnda have proposed a new load balancing technique based on machine learning regression and Classification models [10]. R.Swathy, Anand





Nayyar and G. Rajesh have proposed a new Load Balancing Algorithm which uses the Stackelberg Game Theoretical model for load balancing [11]. K.S. Kannan, Gurram Sunitha and S.N. Deepa have designed a load balancing Algorithm which uses a Micro-Genetic Algorithm with Cat Swarm Optimization [12]. Aarti Singh and Dimple Juneja have proposed an Autonomous Agent based Load balancing Algorithm which is a Dynamic Load Balancing Algorithm for Cloud environment [13]. Ren Gao and Juebo Wu have proposed a new load balancing Algorithm based on ant colony optimization [14]. N.Thilagavathi and D.Divya Dharani have proposed a new Clustering based load balancing Algorithm for Energy Efficient load balancing in Cloud computing [15]. JongBeomeLim and DaeWon Lee have proposed a new Load Balancing Algorithm for mobile devices which is based on a graph colouring implementation based on a genetic algorithm [16]. Hanuman Reddy N and Amit Lathigara have proposed a load balancing algorithm which uses Manta ray foraging (MRF) technique [17]. Mohit Kumar and S.C.Sharma have proposed a new load balancing Algorithm based on last optimal k-interval [18].

Proposed Model

Load balancing is a major concern in cloud computing as cloud computing works in resourced sharing mode. If a certain server is being overloaded while others are underutilized it will degrade the performance. Load balancing refers to the concept of balancing load in different servers. In this work a load balancing algorithm has been proposed utilizing processor capacity, storage capacity, runtime memory capacity and network congestions.

When jobs are coming to the servers for processing servers weight are selected as per following mathematical equation:

$$Weight_i = \frac{P_i * M_i * St_i}{NC_i} \quad (1)$$

Where P_i =Processing capacity of i th Server

M_i =Main Memory capacity of i th Server

St_i =Storage capacity of i th Server

NC_i =Network Congestion of i th Server.

Through the inclusion of these criteria in the weight calculation, the algorithm seeks to offer a thorough evaluation of each server's capacity to manage incoming jobs. Job dispatching intelligently assigns the highest weight server to handle the jobs that are sent to it for processing. The risk of overloading any one server is reduced while maximizing system performance thanks to this assignment technique, which makes sure that jobs are spread in a way that makes the most of each server's strengths. Cloud service providers can increase scalability, improve system responsiveness, and more effectively use resources by utilizing this load balancing method. Additionally, because the algorithm depends on objective parameters, it can be adjusted to different workload scenarios and network dynamics, which makes it more applicable in a variety of cloud computing scenarios.

RESULT ANALYSIS

In this section, the proposed algorithm have been tested and result has been represented. Processing capacity, Main memory capacity, storage capacity and Network congestion has been considered for selecting server for assigning job. In the below mentioned figure 1 ,2,3 and 4 sample Processing capacity, Memory capacity , Storage capacity and Network congestion values considered for this experiment have been shown. Utilizing above mentioned equation no-1 weight of each server is calculated. A sample execution of the proposed algorithm for calculating server weight has been shown in the figure 5 below. It has been identified that the seventh server has height weight so it would be selected to assign job first. In the below.





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CONCLUSION

In this study, a novel load balancing method designed for modern cloud computing systems is presented. The suggested approach improves task allocation to reduce server overload and improve system performance by carefully assessing server characteristics and utilizing intelligent job dispatching. Its adaptability to different workload circumstances and network conditions highlights how useful it is in a variety of real-world cloud computing applications. With a refined approach to maximizing resource consumption and system scalability in cloud computing systems, this work offers a substantial development in load balancing approaches. Future studies on scalability and efficiency improvements could open the door for more developments in cloud computing services and technology.

REFERENCES

1. Abiodun Kazeem Moses, Awotunde Joseph Bamidele, Ogundokun Roseline Oluwaseun, Sanjay Misra & Adeniyi Abidemi Emmanuel (2021) Applicability of MMRR load balancing algorithm in cloud computing, *International Journal of Computer Mathematics: Computer Systems Theory*, 6:1, 7-20, DOI: 10.1080/23799927.2020.1854864 <https://www.tandfonline.com/doi/abs/10.1080/23799927.2020.1854864>
2. A. Francis Saviour Devaraj, Mohamed Elhoseny, S. Dhanasekaran, E. Laxmi Lydia, K. Shankar, Hybridization of firefly and Improved Multi-Objective Particle Swarm Optimization algorithm for energy efficient load balancing in Cloud Computing environments, *Journal of Parallel and Distributed Computing*, Volume 142, 2020, Pages 36-45, ISSN 0743-7315, <https://doi.org/10.1016/j.jpdc.2020.03.022>. <https://www.sciencedirect.com/science/article/abs/pii/S0743731520300459>
3. Rajeev Kumar Gupta, Rajesh Kumar Pateriya Balance Resource Utilization (BRU) Approach for the Dynamic Load Balancing in Cloud Environment by Using AR Prediction Model Source Title: *Journal of Organizational and End User Computing (JOEUC)* DOI: 10.4018/JOEUC.2017100102
4. Shang-Liang Chen, Yun-Yao Chen, Suang-Hong Kuo, CLB: A novel load balancing architecture and algorithm for cloud services, *Computers & Electrical Engineering*, Volume 58, 2017, Pages 154-160, ISSN 0045-7906, <https://doi.org/10.1016/j.compeleceng.2016.01.029>. <https://www.sciencedirect.com/science/article/abs/pii/S0045790616300234>
5. G. Xu, J. Pang and X. Fu, "A load balancing model based on cloud partitioning for the public cloud," in *Tsinghua Science and Technology*, vol. 18, no. 1, pp. 34-39, Feb. 2013, doi: 10.1109/TST.2013.6449405.
6. . Ramezani, F., Lu, J. & Hussain, F.K. Task-Based System Load Balancing in Cloud Computing Using Particle Swarm Optimization. *Int J Parallel Prog* 42, 739–754 (2014). <https://doi.org/10.1007/s10766-013-0275-4> <https://link.springer.com/article/10.1007/s10766-013-0275-4>
7. Chetan Kumar, Sean Marston, Ravi Sen & Amar Narisetty (2022) Greening the Cloud: A Load Balancing Mechanism to Optimize Cloud Computing Networks, *Journal of Management Information Systems*, 39:2, 513-541, DOI: 10.1080/07421222.2022.2063551 <https://www.tandfonline.com/doi/abs/10.1080/07421222.2022.2063551>
8. D. Puthal, M. S. Obaidat, P. Nanda, M. Prasad, S. P. Mohanty and A. Y. Zomaya, "Secure and Sustainable Load Balancing of Edge Data Centers in Fog Computing," in *IEEE Communications Magazine*, vol. 56, no. 5, pp. 60-65, May 2018, doi: 10.1109/MCOM.2018.1700795. <https://ieeexplore.ieee.org/abstract/document/8360851>
9. Zhao Tong, Xiaomei Deng, Hongjian Chen, Jing Mei, DDMTS: A novel dynamic load balancing scheduling scheme under SLA constraints in cloud computing, *Journal of Parallel and Distributed Computing*, Volume 149, 2021, Pages 138-148, ISSN 0743-7315, <https://doi.org/10.1016/j.jpdc.2020.11.007>.
10. Nilayam Kumar Kamila, Jaroslav Frnda, Subhendu Kumar Pani, Rashmi Das, Sardar M.N. Islam, P.K. Bharti, Kamalakanta Muduli, Machine learning model design for high performance cloud computing & load balancing resiliency: An innovative approach, *Journal of King Saud University - Computer and Information Sciences*, Volume 34, Issue 10, Part B, 2022, Pages 9991-10009, ISSN 1319-1578, <https://doi.org/10.1016/j.jksuci.2022.10.001>. <https://www.sciencedirect.com/science/article/pii/S1319157822003524>





Annwasha Banerjee Majumder et al.,

11. Swathy R, Vinayagasundaram B, Rajesh G, Nayyar A, Abouhawwash M, Abu Elsoud M (2020) Game theoretical approach for load balancing using SGMLB model in cloud environment. PLoS ONE 15(4): e0231708.<https://doi.org/10.1371/journal.pone.0231708><https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0231708>
12. K.S. Kannan, Gurram Sunitha, S.N. Deepa, D. Vijendra Babu, J. Avanija, A multi-objective load balancing and power minimization in cloud using bio-inspired algorithms, Computers and Electrical Engineering, Volume 102, 2022, 108225, ISSN 0045-7906, <https://doi.org/10.1016/j.compeleceng.2022.108225>.
13. Aarti Singh, Dimple Juneja, Manisha Malhotra, Autonomous Agent Based Load Balancing Algorithm in Cloud Computing, Procedia Computer Science, Volume 45, 2015, Pages 832-841, ISSN 1877-0509,<https://doi.org/10.1016/j.procs.2015.03.168>.
14. Gao R, Wu J. Dynamic Load Balancing Strategy for Cloud Computing with Ant Colony Optimization. *Future Internet*. 2015; 7(4):465-483. <https://doi.org/10.3390/fi7040465>
15. N. Thilagavathi, D. Divya Dharani, R. Sasilekha, Vasundhara Suruliandi, V. Rhymend Uthariaraj Energy Efficient Load Balancing in Cloud Data Center Using Clustering Technique International Journal of Intelligent Information Technologies (IJIT) 15(1)
1. <https://www.igi-global.com/article/energy-efficient-load-balancing-in-cloud-data-center-using-clustering-technique/221354>
16. Lim, JongBeom, and DaeWon Lee. 2020. "A Load Balancing Algorithm for Mobile Devices in Edge Cloud Computing Environments" *Electronics* 9,no.4:686.<https://doi.org/10.3390/electronics9040686><https://www.mdpi.com/2079-9292/9/4/686>
17. N., H.R., Lathigara, A., Aluvalu, R. and V., U.M. (2023), "Clustering based EO with MRF technique for effective load balancing in cloud computing", *International Journal of Pervasive Computing and Communications*, Vol. ahead-of-print No. ahead-of-print. <https://doi.org/10.1108/IJPCC-01-2023-0022> <https://www.emerald.com/insight/content/doi/10.1108/IJPCC-01-2023-0022/full/html>
18. Mohit Kumar, S.C. Sharma, Deadline constrained based dynamic load balancing algorithm with elasticity in cloud environment, Computers & Electrical Engineering, Volume 69, 2018, Pages 395-411, ISSN 0045-7906, <https://doi.org/10.1016/j.compeleceng.2017.11.018>.<https://www.sciencedirect.com/science/article/abs/pii/S004579061731073X>

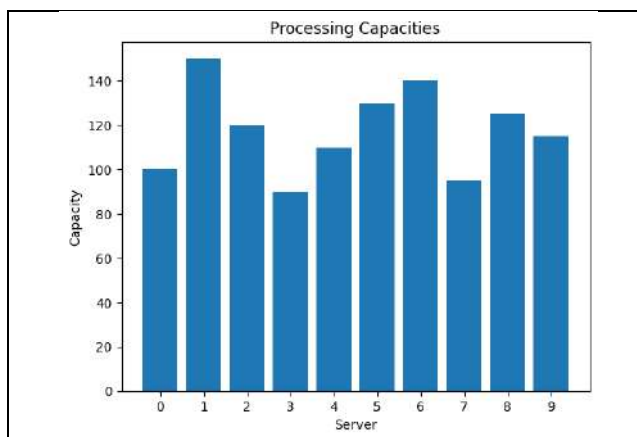


Fig 1: Processing Capacity of Sample Servers

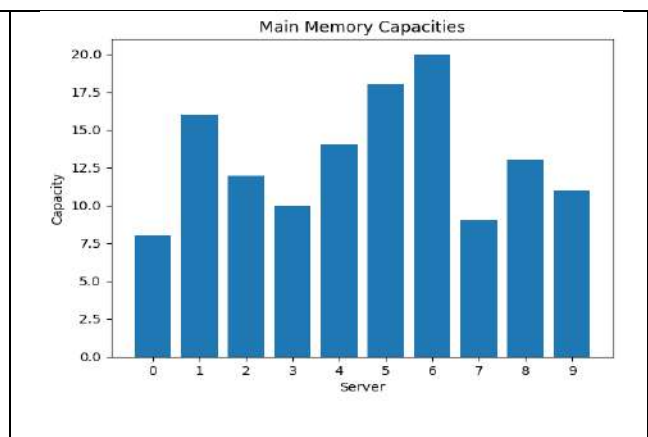


Fig 2: Main Memory Capacity of Sample Servers





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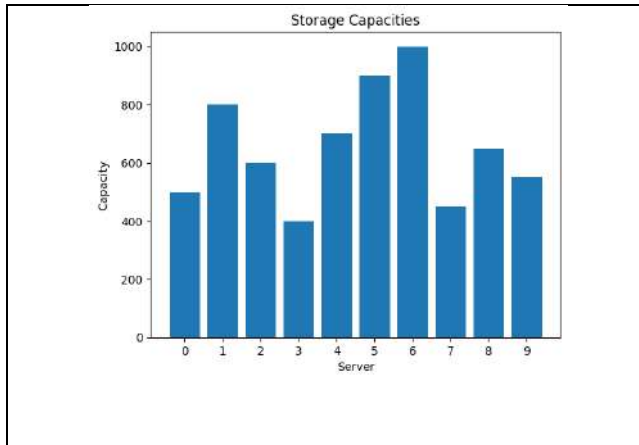


Fig 3: Storage capacity of Sample Servers

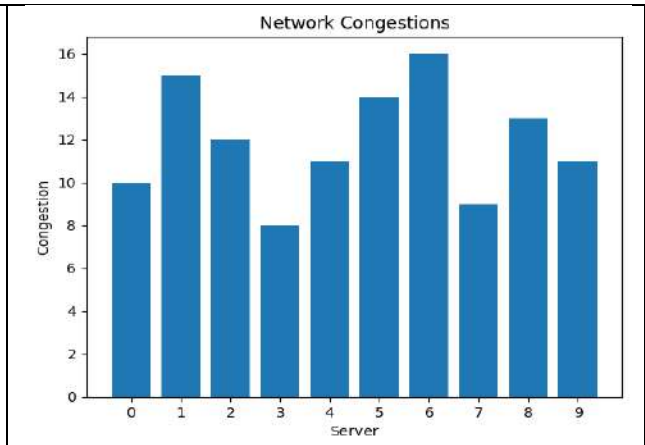


Fig 4: Network Congestion in each Sample Servers

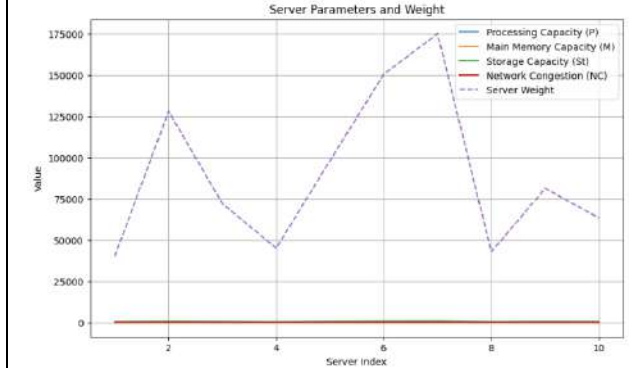


Fig 5: Calculation of Server weight.

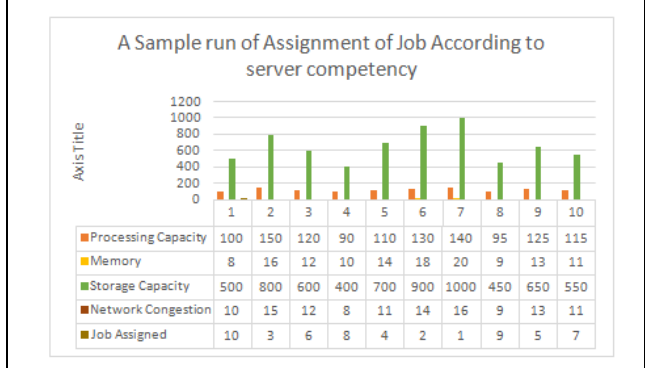


Fig 6: Job Assignment to Servers.





Baryte Mineralization and its Characters from a Part of Hungund-Kushtagi Schist Belt, Bagalkote District, Eastern Dharwar Craton

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ABSTRACT

Baryte, one of the most crucial non-metallic resources, is primarily used in the oil and gas exploration industry. Many deposits of baryte are found in different parts of the world, including in India. The present study of baryte mineralization in a part of the Archaean Hungund-Kushtagi Schist Belt is aimed at investigating the control on its occurrence and its chemical composition. As a result of this study, it is found that the baryte mineralization in this area occurs in both, younger granites and the schistose rocks, and its mineralization is controlled by the fractures. Chemical analysis has revealed that the barium sulphate concentration varies widely and the comparatively higher concentration of barium sulphate occurs in both, the white and pink varieties of baryte. This study contributes to the database on baryte mineralization in India, especially in the state of Karnataka.

Keywords: Baryte (Barite), Hungund-Kushtagi Schist Belt, Dharwar Craton, Karnataka.



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INTRODUCTION

Baryte, the mineral form of barium sulphate (BaSO_4), has many applications in different industries. It is used as a drilling mud while exploring for oil and gas, a raw material for production of compounds of barium, in the manufacture of glass and ceramics[1]; as a filler, extender and aggregate in rubber, plastics and paint industries, in automobile industries for various purposes, in metal casting industries, and in nuclear power-generation plants and nuclear research centres [2, 3]. Oil and gas industry is the primary consumer of baryte. Baryte, characterized by its higher specific gravity and thus called heavy spar, occurs mainly in four forms viz. sedimentary bedded, volcanic bedded, cavity-fill (hydrothermal mineralization), veins and metasomatic, and residual. Major occurrences of baryte belong to the first form [2]. According to [4], the concentration of baryte is about 0.062 wt% in the upper continental crust. Although it has a lower crustal abundance, there are instances of large scale accumulation in different parts of the world. Along with China, India is one of the largest producers of Baryte [2]. The total reported reserves/resources of baryte in India stand at 86.67 million tons out of which the maximum production is from Andhra Pradesh. The total resources in Andhra Pradesh alone amount to nearly 79.5 million tons. Karnataka produced 345 tons of baryte during 2019-20 and is reported to have total resources of 243943 tons [5]. In Karnataka, stratified (bedded) baryte within quartzite was reported in 1974 from the Ghattihosahalli Schist Belt[6]. The bed was first located nearly one km WNW of Ghattihosahalli near Talya and has been intermittently traced up to Janakal over a distance of nearly 10 km. Subsequently, many studies related to the quality and size of baryte and associated lithologies have been carried out over a period from 1976 to 2010 [7, 8]. Although there is a continuous increase in the global production of baryte including from countries like Kazakhstan and Turkey, consumers continue to prefer baryte mined in India and China due to their low price. However, it is reported that the price of Chinese baryte has increased by six fold during a span of ten years[2]. Although the deposit at Mangampeta in the Cuddappahs of Andhra Pradesh is the single largest baryte deposit in the world[5], continuously increasing production results in stress. Keeping the above in mind, it is imperative to search and explore new sites. The current study, around Gadisunkapur and Jambaldinni in Bagalkote district, is an attempt to supplement the available data on baryte in India, especially Karnataka. To achieve this, the present study was carried out with the objective of understanding the mode of occurrence of baryte and the controlling factor, and to chemically analyse the concentration of barium sulphate.

REGIONAL GEOLOGY

The current study area, around Gadisunkapur and Jambaldinni in Bagalkote district, is a part of the Archaean Hungund-Kushtagi Schist Belt of the Eastern Dharwar Craton (EDC). The width of this almost NW-SE trending belt varies, with the maximum width being about 15 km. This greenstone belt is disconnected from the Ramagiri – Sirigere Belt by a meagre zone of granitoids and is obscured in the north beneath the rocks of the Proterozoic Kaladgis. Metabasalts occur along the margin of the belt and a metasedimentary unit occurs in the central part. Felsic volcanics along with the metasediments comprising mainly greywacke-phyllite with polymict conglomerates, BIF and ferro-dolomite bands constitute the Hungund-Kushtagi Schist Belt. Pyroxenite and gabbro-anorthosite intrusives occur in the western part of the belt. The schist belt is bound by granite in either side, i.e. on the south-west and north-east[9, 10]. Besides the schist belt rocks, ultramafites (of Kalmangi) forming a layered complex are also a part of the belt; hornblende-biotite granite gneiss of Peninsular Gneissic Complex (PGC II) and pink porphyritic granite and hornblende granite belonging to Closepet Granite are the other lithologies associated with this Schist Belt. All these rock types are successively intruded by younger acid- and basic-intrusive. The regional stratigraphy of the area is given below in Table 1.

Geological setting of the Schist Belt

The present study area is a part of the Hungund-Kushtagi Schist Belt that lies in the Archaean Eastern Dharwar Craton. The Hungund-Kushtagi Schist Belt is disconnected from the Ramagiri-Sirigeri Belt by a meagre zone of granitoids, slightly north of River Tungabhadra, and is obscured in the north beneath the rocks of the Kaladgi Group of Proterozoic age. The belt is conquered by metabasalts along the margins and meta-sedimentary unit at central



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part. The felsic volcanics along with the meta-sediments comprising mainly greywacke-phyllite with polymict conglomerates, BIF and ferro-dolomite bands constitute the Hungund – Kushtagi Schist Belt. Pyroxenite and gabbro-anorthosite intrusives occur in the western part of the belt.

Geology of the study area

Within the study area, amphibolite of Lower Ilkal Formation, quartz chlorite schist and Banded Iron Formation (BIF) of upper Mudenur Formation, pink porphyritic granite of Closepet granite, and younger intrusives (dolerite dyke and quartz veins) are recorded. Other lithounits noticed are massive metabasalt, ultramafics, and grey granite of Closepet granite and younger gabbro. Quartz and baryte veins of variable dimensions have intruded within quartz-chlorite schist and pink Closepet granite. Baryte of different colours (milky white, white and pink) occurs in the form of vein. Massive to crystalline variety of baryte veins are also observed within pink granite. Geological map of the study area is presented as Figure 1. Systematic geological mapping was carried out to assess favourable host rock for baryte mineralization. Quartz- and baryte-veins have intruded both, the quartz-chlorite schist and pink porphyritic granite. A wide variation in the colours of baryte veins from milky white, white to pink is noticed in mapped area. Baryte is mainly of fine massive type to rare crystalline variety.

Structures

Both, primary as well as secondary structures are observed in the study area. Primary structures include bedding, as observed in BIF and marked by compositional colour banding i.e. red and black colour layers. The attitude of the bedding plane is N30°W/72°E. All the rock types in the area have undergone at least three phases of deformations. Two prominent foliation planes were observed in quartz chlorite schist, invariably at an angle to each other.

Three episodes of deformation have been identified in the area viz. S1, S2 and S3. The first episode of deformation (S1) is in the form of schistosity and gneissosity developed in different lithounits like quartz-chlorite schists and biotite granite-gneiss. This deformation (S1) is parallel to the bedding plane (S0), except at the hinge of minor folds. The second episode of deformation (S2) is represented by foliation, on a local scale, developed at the axial plane of the fold. The average attitude of the S1 is N45°W/55°E and that of S2 is N20°W/60°E. Deformation S2 is found to have a very low angle contact with S1. The third episode of deformation (S3) is represented by fractures trending N70°E-S70°W to E-W and joints. Mainly two sets of penetrative joints were noticed but at places, three sets were also noticed. Joints are mostly N-S, E-W or NW-SE trending and dipping steeply. Fractures (S3), axial planar to the kinks and broad wraps (S2), play a significant role in controlling baryte mineralization. Quartz chlorite schist shows well developed foliation planes, whereas joints are very common in granite. Type-III hook-shaped interference pattern is observed within BIF due to the superimposition of F2 over F1.

METHODOLOGY

This current work necessitated systematic geological mapping, sampling and their chemical analysis. Geological mapping was carried out along parallel traverse lines so as to mark the litho-contacts. A GPS receiver unit along with Brunton Compass were employed during geological mapping. Baryte sampling was carried out by cutting grooves of 5-6 cm width having a depth of 2-3 cm. Specific interval of sampling was not adopted as baryte occurs in the form of discontinuous veins filling the fractures. Samples weighing 1 to 1.5 kg were collected and they were ground to -200 mesh size. Sample reduction was achieved by subjecting the sample-powder to coning and quartering method so as to get a sample of about 200 gm. Each of the samples was analyzed for their barium sulphate concentration by wet chemical methods.



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RESULTS AND DISCUSSION

Baryte mineralization

On the basis of different criteria such as physical and chemical characters, and geological setting, baryte occurrence can be grouped in to four categories viz. (i) sedimentary bedded mode of occurrence, (ii) volcanic bedded mode, (iii) veins, stringers, cavity fills, and metasomatic mode, and (iv) residual mode[2]. Large deposits of baryte belong to the sedimentary bedded type wherein baryte occurs as stratiform massive bodies in sedimentary formations[2]. The large baryte deposit at Mangampeta in Andhra Pradesh is a classic example of this type of deposit. The sedimentary bedded baryte deposits and sulphide mineralization can co-occur. They can occur together in the form of thin interbedded layers[11], in the form of intergrown crystals[12] and they can also occur adjacent to each other[13, 14]. Volcanic bedded baryte deposits are massive stratiform bodies of baryte that occur within stratigraphic successions that contain both, mafic and felsic volcanics, and sedimentary formations. In this mode of occurrence, high grade baryte deposits can occur with barium sulphate content of about 90%. Metals like zinc, lead, copper and silver- and auriferous-sulphide minerals can occur with baryte in the form of interbedded layers or intergrowths[2]. An example is that of the baryte deposits of Hokaido and Honshu in Japan where zinc, copper and zinc occurrences are well known [15]. The third mode of occurrence is in the form of veins, stringers, cavity filling and metasomatic replacement. Occurrence in the first three forms is the result of baryte occupying open-spaces or weak zones such as fractures, fault planes, breccia zones etc. and the metasomatic mode is due to replacement. Numerous instances of this mode of occurrence have been reported from different parts of the world by different researchers. The residual mode of baryte occurrence results from the weathering of any pre-existing mineralization. In the present study area, baryte mineralization is observed within both, quartz-chlorite schists of Upper Mudenu formation of the Archaean Hungund-Kushtagi Schist Belt and pink porphyritic granites (Closepet granite). Baryte mineralization is observed as secondary fracture fill hydrothermal vein type. The trend of baryte veins varies from N70°E – S70°W to E-W within pink granites and NNW-SSE, NE to E-W in the quartz-chlorite schists. Baryte occurrences are observed well in stream- (nala) and pond-sections in the study area. Baryte veins are identified in seven places, out of which two veins are hosted within quartz-chlorite schists and remaining ones within pink porphyritic Closepet granites.

Baryte mineralization in quartz-chlorite schist

It is observed NW of Gadisunkapur and south of Tarival with a strike length of 200m. Here, the width of the baryte veins varies from 0.5 to 4m. The trend varies from NNW-SSE, N55°E to E-W. In Tarival area, it trends NNW-SSE and the width of 0.2 to 0.8m and a strike length of 50m. Milky white to pinkish baryte veins are seen in this lithounit. Figures 2 and 3 indicate occurrence of baryte within quartz-chlorite schists.

Baryte mineralization in pink porphyritic granite

These are observed at five places viz. north-west of Gadisunkapur; east, south-east and south of Jammaldinni; and east of Kesharbhavi. Width of baryte vein varies from 20cm to 4m. The 4m wide body was observed in a stream (nala) section, located south-east of Jammaldinni. Baryte veins are generally trend N70°E-S70°W to E-W. Baryte is white, milky white to pink in colour, and crystalline in nature. A typical pinkish baryte with blue inclusions is observed within pink granite. Figures 4 and 5 depict baryte occurrences within pink granites.

Sampling and chemical analysis

With an objective of analysing the samples for their barium sulphate concentration, a total of ten samples were collected from the study area. The ten samples were collected from both, Gadisunkapur area and Jambaldinni area. They have been named as BRG and BRJ respectively. The samples were collected primarily from within quartz-chlorite schist and pink porphyritic granites. The results are presented in Table 2. From the above Table 1, it is clear that there is a wide variation in the BaSO₄ concentration, from a minimum of about 25% to a maximum of >74%. Although lower BaSO₄ concentration (~ 25 to 45%) is reported from milky-white baryte samples (BRG2, BRJ3, BRJ4 and BRJ5), higher BaSO₄ concentration is also reported from some of them (BRG4, BRJ1, and BRJ2). It is interesting to know that the two pink baryte vein samples (BRG1 and BRG3) have higher BaSO₄ concentration.





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CONCLUSIONS

Systematic geological mapping has revealed the presence of baryte mineralization in the study area. It is observed that baryte mineralization occurs within and outside the Hungund-Kushtagi Schist Belt. Within the schist belt, it occurs in the quartz-chlorite schists of Upper Mudenur formation. Just outside the schist belt, baryte mineralization is recorded from the pink porphyritic granites. Out of the seven baryte occurrences, five are in pink porphyritic granites. The baryte mineralization, of white and pink colours, occurs as secondary fillings and is thus controlled by deformations such as fractures. Chemical analysis has revealed that the barium sulphate concentration varies greatly and the highest concentration is around 74%. Although lower barium concentration, in the range of ~ 25 to 45% is reported from the white variety, higher barium sulphate concentration (63 to 74%) is reported from both, white and pink varieties of baryte.

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REFERENCES

1. Indian Bureau of Mines, "Indian Minerals Yearbook 2014 – Part III: Mineral Reviews, 53rd Edition – Barytes (Final Release). 2016:1-11."
2. C. A. Johnson, N. M. Piatak and M. M. Miller, "Baryte (Barium)", chapter D of Schulz, KJ, DeYoung, JH Jr., Seal, RR II, Bradley, DC. (Editors) "Critical mineral resources of the United States—Economic and environmental geology and prospects for future supply: United States Geological Survey (USGS) Professional Paper 1802 2017:D1–D18".
3. D. Alderton and S. A. Elias (Editors), "Encyclopedia of Geology", 2nd edition, ISBN 978-0-08-102909-1. 2021.
4. R. L. Rudnick and S. Gao, "Composition of the Continental Crust". In: H. D. Holland and K. K. Turekian (Editors), "Treatise on Geochemistry", 2nd edition. ISBN 978-0-08-098300-4. 2003.
5. Indian Bureau of Mines, "Indian Minerals Yearbook 2020 – Part III: Mineral Reviews, 59th Edition – Minor Minerals, Barytes (Advance Release), 2021:1-5".
6. B. P. Radhakrishna and C. Sreenivasaiya, "Bedded barytes from the Precambrian of Karnataka". Journal of Geological Society of India. 1974:15:314-317.
7. G. S. Annaiya and C. Srinivasaiah, "Baryte deposit of Ghattihosahalli, Kumminaghatta, Janakal area, Holalkere and Hosagurgataluks, Chitradurga District". Department of Mines and Geology, Bangalore. Geological Studies No. 112. 1976:1-19.
8. C. G. Nevinand H. S. Pandalai, "Fluid inclusion studies on baryte from Hutti Gold Mines, Karnataka, India: inferences on late-stage hydrothermal fluid". Current Science. 2010: 98(7):955-962.
9. P. G. K. Bhat, "Specialised thematic mapping of Hungund-Kushtagi-Hagari Schist belt in parts of Hungund and Kushtagitaluks of Bijapur and Raichur Districts, Karnataka state (Field Season 1994-95)". Geological Survey of India, Government of India. 1999.
10. H. Nagaraja, P. A. Sinha and C. Chakerabarti, "Geological mapping in part of Hungund, Bagalkot and Muddebihal taluks of Bijapur district, Kushtagi & Lingsugertaluks of Raichur district & Shorapur taluk of Gulbarga district, Karnataka State (Progress report for the field season 1977-78)". Geological Survey of India, Government of India. 1982.
11. W. D. Goodfellow, "Geology, genesis and exploration of SEDEX deposits, with emphasis on the Selwyn basin, Canada. In: Deb Mihir, Goodfellow WD. (Editors) Sediment-hosted lead-zinc deposits - Attributes and models of some major deposits in India, Australia, and Canada": Narosa Publishing, New Delhi, India. 2004.





Ramaling D Natikar et al.,

12. K. D. Kelley, D. L. Leach, C. A. Johnson, J. L. Clark, Fayek Mostafa, J. F. Slack, V. M. Anderson, R. A. Ayuso and W. I. Ridley, "Textural, compositional, and sulfur isotope variations of sulfide minerals in the Red Dog Zn-Pb-Ag deposits, Brooks Range, Alaska - Implications for ore formation". *Economic Geology*. 2004:99:1509–1532.
13. D. Large and E. Walcher, "The Rammelsberg massive sulphide Cu-Zn-Pb-Ba-deposit, Germany - An example of sediment-hosted, massive sulphide mineralisation". *Mineralium Deposita*. 1994:34(5–6):522–538.
14. C. R. McClung, Gutzmer Jens, N. J. Beukes, Mezger Klaus, Strauss Harald and Gertloff Ellen, "Geochemistry of bedded baryte of the Mesoproterozoic Aggeney-Gamsberg Broken Hill-type district, South Africa". *Mineralium Deposita*. 2007:42:537–549.
15. Marumo Katsumi. "The baryte ore fields of kuroko-type of Japan, In de Brodtkorb M D (Editor) *Nonmetalliferous stratabound ore fields*". Van Nostrand Reinhold, New York, N.Y. 1989:201–231.

Table 1: Regional stratigraphy

Lithology	Formation	Group	Supergroup	Age
Quartz, pegmatite and aplite veins	Acid Intrusive	Younger intrusive		Palaeoproterozoic
Dolerite and Gabbro dyke	Basic intrusive			
Grey and pink biotite granite		Closepet granite		
Hornblende biotite granite gneiss	Gneisses	PGC_II	Peninsular gneissic Complex	Archaean to Palaeoproterozoic
Ultramafite	Kalmangi Ultramafic	Layered Ultramafic Complex		
Banded Iron Formation, Chert with argillite	Mudener Formation	Hunugund-Kushtagi Schist Belt	Dharwar Supergroup	Archaean
Quartz chlorite schist				
Metagabbro	Ilkal Formation			
Metabasalt				
Amphibolite				

Table 2: Results of chemical analysis of baryte samples from the study area

S. No	Sample No.	Description	BaSO ₄ %
1	BRG1	Pink baryte vein	63.83
2	BRG2	Milky white to pink baryte	33.96
3	BRG3	Pink baryte vein	73.45
4	BRG4	Milky white baryte vein	64.70
5	BRG5	25cm thick baryte vein found within quartz chlorite schist	37.47
6	BRJ1	Milky white baryte veins	74.32
7	BRJ2	Milky white baryte veins	73.42
8	BRJ3	Thin milky white quartz/baryte veins and width varies from 5 to 15cm found within pink granite	33.01
9	BRJ4	Baryte veins (milky white) of width varying from 7 to 10cm found within pink granite	25.33
10	BRJ5	Thin milky white quartz/baryte veins and width varying from 5 to 15cm found within pink granite	46.00





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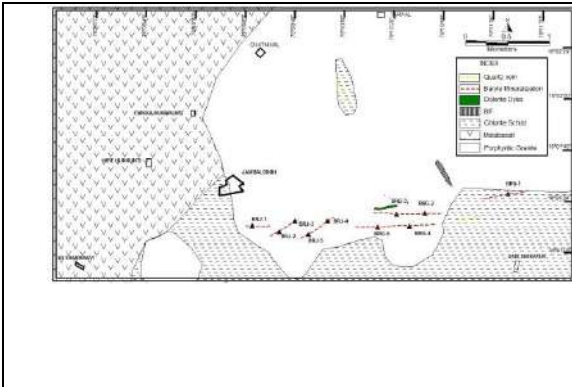


Figure 1: Geology of the area around Gadisunkapur and Jambaldinni, Hungund-Kushtagi Schist Belt, Bagalkote district, Karnataka.



Figure 2: A vein of baryte within quartz-chlorite schist



Figure 3: Copper oxidation along the fracture of baryte within quartz-chlorite schist



Figure 4: An outcrop of baryte within pink porphyritic granite



Figure 5: Baryte exposure in a stream bed, south east of Jambaldinni





Excision of Fibroma by Laser-A Case Report

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ABSTRACT

Gingival overgrowth is one of the most often reported complaints of the gingiva. Due to variation in the size, extent, and location of the gingival overgrowth. It becomes a grueling task for the clinician to make a suitable diagnosis. It is imperative that the clinician performs all the necessary investigations in order to formulate an adequate treatment plan and decide the method of treatment. It is also important to remember that mouth being the mirror of the body, different conditions could be indicative of various systemic conditions one could be affected with.

Keywords: Gingival Enlargement, Laser, Excisional Biopsy, Fibroma

CASE REPORT

A 48-year-old aged female patient reported to the Department of Periodontology Faculty of Dental Sciences, SGT University with a principal concern of the inability to close her mouth for 1-2 years. This was due to the growth which could be appreciated on the upper front tooth region for the same duration. The patient did not state any previous family or medical history. (Fig- 1) On extraoral examination, incompetence of lips was observed at rest position and swelling was seen in the upper front region of face. The face of the patient was bilaterally symmetrical. On TMJ examination, the interincisal opening was 35 mm, there was no deviation observed. There was no clicking or popping sound produced, the patient did not complain of any pain in opening or closing the mouth. There was no crepitus present. The lymph nodes were nontender and non-palpable on examination. The intraoral examination





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presented a firm, large solitary pedunculated mass. It was lobulated pale pink exophytic growth. It comprised of some erythematous areas which primarily involved the attached gingiva and buccal interdental papilla wrt 21,22. (FIG-II) The lesion has smooth and shiny surface, measuring approximately 11 mm[occluso-gingivally] (FIG-III) and 13 mm [mesiodistally wrt 21,22] (FIG-IV). The patient had no previous eventful dental history. The treatment adopted was the complete surgical excision. The patient was instructed regarding the complete procedure, the adequate consent was obtained prior to the surgery. A blood hemogram was taken to the Department of Pathology wherein no significant findings could be observed. Antibiotic prophylaxis was given before the procedure. Extra-oral and intra-oral antiseptics were done with 5% povidone-iodine solution. Local infiltration in the area of the enlarged tissue was done using 2% lidocaine hydrochloride with 1:80,000 adrenaline. The complete lesion was excised with the help of a soft tissue laser (980 nm wavelength at 3 watts with contact mode). (FIG-V). Suture or Coe-Pack was not placed. (FIG-VI) A histological examination was done in the Oral Pathology Department.(FIG-VI). Post-operative instructions were given. Oral Amoxicillin 500 mg thrice a day and Oral Zerodol P were prescribed twice a day for 3 days. (FIG-VII). The histopathological features were diagnostic of Fibroma showing epithelium and connective tissue stroma. Stratified squamous epithelium is observed. The underlying connective tissue was composed of dense collagen bundles and numerous blood vessels. (FIG-VIII). The healing observed in the surgical regions was found to be uneventful. The lesion had completely resolved. The patient was recalled for a follow-up visit after 1 month and 3 months consequently and the healing was found to be satisfactory. (FIG-IX & FIG-X).

DISCUSSION

Gingival overgrowth can occur as a result of a number of stimulants which could be either local or systemic.[1] These lesions observed could be present in a localized area or present in a generalized form [2]. The gingival overgrowth could either be sessile or pedunculated. The etiology of the enlargement could depend on an array of factors namely hormonal imbalances, systemic incarnation etc [3]. The question arises so as to why these clinical presentations are important to us for distinguishing as it may affect mastication, speech, tooth eruption, and even aesthetics [4]. The applicable mode of treatment could depend on the principal complaint, the degree of involvement, the duration, and the association with a systemic disease [5]. It is extremely important to take a detailed medical history from the patient. Any surgical remedy is desirable in order to fulfill an aesthetic or functional requirement [6]. It is very important to work on the patient's mindfulness and provocation along with a timely visit. It is extremely important to follow instructions given by the clinician, follow plaque control, and observe for any remission [7,8].

CONCLUSION

The treatment of choice is largely impacted by the size of the enlarged tissue, the duration the lesion has existed, and the resources of the patient. Examination and history taking are extremely important for the treatment of Gingival overgrowth cases.

REFERENCES







1. Esmeili T, Lozada-Nur F, Epstein J. Common benign oral soft tissue masses. *Dent Clin North Am.* 2005;49:223–40.
2. Naderi NJ, Eshghyar N, Esfehianian H. Reactive lesions of the oral cavity: a retrospective study on 2068 cases. *Dent Res J.* 2012;9:251–5.
3. Bouquot JE, Gundlach KK. Oral exophytic lesions in 23,616 white Americans over 35 years of age. *Oral Surg Oral Med Oral Pathol.* 1986;62:284–91.
4. Dhanuthai K, Rojanawatsirivej S, Somkotra T, et al. Geriatric oral lesions: a multicentric study. *Geriatr Gerontol Int.* 2016;16:237–43.
5. Alaeddini M, Barghamadi R, Eshghyar N, et al. An analysis of biopsy-proven tongue lesions among 8,105 dental outpatients. *J Contemp Dent Pract.* 2014;15:1–7.





Aditi Chaturvedi et al.,





6. Neville BW, Damm DD, Allen CM, et al. *Oral and Maxillofacial Pathology*. Philadelphia, USA: Saunders/Elsevier; 2009.
7. Valério RA, de Queiroz AM, Romualdo PC, et al. Mucocele and fibroma: treatment and clinical features for differential diagnosis. *Braz Dent J*. 2013;24:537–41.
8. Parwani S, Parwani RN. Diagnosis and management of focal reactive overgrowths of gingival: a case series. *J Mich Dent Assoc*. 2014;96:36–47.

	
<p>Fig- 1- Pre-Operative Photograph; Lesion wrt 21,22</p>	<p>Fig-II-Type of Lesion - a largely solitary, hard pedunculated mass</p>
	
<p>Fig-III-Dimension of Lesion 11 mm (occluso-gingivally)</p>	<p>Fig-IV-Dimension of Lesion 13mm (mesiodistally wrt 21,22)</p>
	
<p>Fig-V- Intraoperative Photograph-Excision of The Lesion Using Laser</p>	<p>Fig-VI- Excised Lesion 11mmx13mm</p>





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<p>Fig-VII- Immediate Post Operative</p>	<p>Fig-VIII- Photomicrograph 10x displaying histopathological features of Fibroma.</p>
	
<p>Fig -IX -1 Month Post Operative Photograph</p>	<p>Fig -X -3 Months Post Operative Photograph</p>





Preliminary Phytochemical Screening, FT-IR Spectral analysis, and Assessment of *in-vitro* Antibacterial Activity of Methanolic Crude Extract of *Alpinia galanga* (L.) Willd

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ABSTRACT

The Zingiberaceae family of *Alpinia galanga* (L.) Willd., also referred to as greater galangal, is an aromatic perennial herb that is mostly grown in India, China, Thailand, Malaysia, and Indonesia. It has been used medicinally for a long time. It is frequently used as an aromatic stimulant or flavoring in cooking, and it is also a traditional treatment for bronchial catarrh, asthma, and rheumatism. The present study assessed the antibacterial efficacy of *Alpinia galanga* methanolic rhizome crude extract, as well as its qualitative phytochemical analysis and functional group presence as determined by Fourier Transform Infrared spectrophotometer (FT-IR) analysis. The presence of flavonoids, alkaloids, carbohydrates, tannins, saponins, phytosterols, and coumarins is shown by phytochemical screening. The highest zone of inhibition for antibacterial activity was seen against *Staphylococcus aureus* for gram-positive bacteria and *Escherichia coli* for gram-negative bacteria. Functional group of *Alpinia galanga* was analyzed using a Fourier transform infrared spectrophotometer (FT-IR), which revealed the presence of amines, carboxylic acids, alkanes, alkenes, and nitro compounds. Numerous phytochemical components, functional groups, and antibacterial potential suggest that it can be utilized to combat pathogenic bacteria that affect humans as well as to manage various diseases and enhance immunity renewal.

Keywords: *Alpinia galanga*, Phytochemical, FT-IR, Antibacterial, functional group



**Rabita and Palanisamy****INTRODUCTION**

Phytochemicals are compounds that occur naturally in medicinal plants, leaves, roots, and vegetables; they have particular functions and provide protection against disease. Because to sophisticated results and better equipment, phytochemical investigations are attracting the interest of plant scientists more and more. These techniques are essential for finding important data related to the pharmaceutical industry [1]. The phytochemicals found in plants that are in charge of preventing illness and enhancing health have been the subject of in-depth research to determine their effectiveness and comprehend the underlying mechanisms of their action. The chemical components have been identified and isolated, and their biological potency has been established by in vitro and in vivo research in experimental animals as well as epidemiological and clinical-case control studies in humans [2]. Phytochemicals are categorized as either major or secondary ingredients based on how they function within the metabolism of plants. Common sugars, proteins, amino acids, pyrimidines and purines found in nucleic acids, chlorophyll, etc. are examples of primary components. The other plant compounds, including lignans, alkaloids, terpenes, flavonoids, curcumines, saponins, phenolics, flavonoids, and glucosides, are considered secondary components [3]. Phytochemicals come in thousands of recognized and many undiscovered varieties. Although it is commonly known that plants make these compounds to defend themselves, new studies have shown that many phytochemicals can also shield humans from illness [4]. *Alpinia galanga* (L.) Willd. is a perennial herb primarily grown in India, China, Thailand, Malaysia, and Indonesia that is a member of the Zingiberaceae family. Greater galangal, or *Alpinia galanga*, is also referred to as kulanjan in Hindi and Kanghoo in Manipuri [5]. Many *Alpinia* species are valued for their therapeutic qualities and are employed in traditional Chinese and Indian medicine for their anti-inflammatory, hypotensive, anti-emetic, anti-oxidant, and bacteria and fungi-static activities [6].

Alpinia galanga is often used as a flavoring or aromatic stimulant in cooking, as well as a traditional remedy for rheumatism, asthma, and bronchial catarrh [7]. *Alpinia galanga* is one among the several components included in polyherbal remedies used to treat a variety of etiologies of pain, including rheumatoid arthritis, back pain, and pain in South Indians who have contracted Chikungunya disease [8]. Numerous secondary metabolites, including terpenoids, flavonoids, and phenylpropanoids, are present in *Alpinia galanga* [9]. Terpenen-4-ol is among the most active substances identified. This plant also contains other significant phytoconstituents such as alkaloids, saponins, glycosides, phenolics, flavonoids, phytosterols, and carbohydrates [7]. From ethanolic preparations of *Alpinia galanga*, galango flavonoid, a recently discovered flavonoid was extracted [10]. Several pharmacological active compounds with potential applications such as antitumor, antioxidant, antifungal, antibacterial, gastroprotective, hypolipidemic, and anti-inflammatory properties have been discovered to be present in the rhizome extract of *Alpinia galanga* [11]. Several researchers have also discovered that *Alpinia galanga* methanolic and aqueous extracts demonstrated substantial anion superoxide scavenging activity, metal chelating activity, and significant free radical scavenging capacity against DPPH radical. Additionally, the in vitro inhibition of α -glucosidase and α amylase, together with its strong antibacterial activity, were discovered to be achieved by the ethanolic extract of galangal [12,13]. According to the GC-MS study, selinene, farnesene, 1,2-benzenedicarboxylic acid, germacrene B, and pentadecane are the minor constituents of galanga extract, whereas 1,8-cineole, β -bisabolone, and β -selinene are the main constituents. The unique scent of *Alpinia galanga* is attributed to active substances such as hydroxyl-1,8-cineole, glucopyranosides, and (1R, 2R, 4R)-trans-2-hydroxyl-1,8-cineole (1S, 2S, 4R) [7]. The present study consists of preliminary phytochemical analysis, assessment of *in-vitro* antibacterial activity and FT-IR spectrophotometer analysis to check the functional group present in the extract of *Alpinia galanga*.

MATERIALS AND METHODS**Plant Taxonomy**

The identification of the plant species *Alpinia galanga* was successfully performed at the Plant Taxonomy Laboratory, Department of Botany, Annamalai University, Tamil Nadu.



**Rabita and Palanisamy****Collection, identification and authentication of plant material**

An indigenous medicinal plant *Alpinia galanga* known by a local name Kanghoo in Manipuri. The fresh rhizomes of *Alpinia galanga* was collected in the month of March 2023 from Laphupat Tera in Bishnupur District, Manipur, NE, India. Professional botanists Dr. D. Kumarasamy, Professor in the Department of Botany at Annamalai University, verified the taxonomy and authenticity of the plant material. The plant voucher specimen was given to the university so that it might be used again.

Processing and preparation of plant material

After thoroughly washing the collected plant material under running water and then with distilled water, it was allowed to air dry for 15 to 30 days at room temperature. After being dried and ground into a somewhat coarse powder, the rhizomes were preserved for later use in an airtight container.

Preparation of extract

The crude rhizome was extracted using the Soxhlet apparatus. 500 ml of methanol solvent is used for extraction, and a thimble containing 100 g of powdered plant material was uniformly filled. The solvent was gradually evaporated from the crude extract using a rotating vacuum evaporator set at 60°C. The extracted crude is kept cold until further analysis.

Percentage yield of extract

The percentage yield of methanolic extract was calculated by using the following formula.

$$\text{Percentage of yield (\%)} = \frac{\text{weight of extract}}{\text{weight of dry plant powder}} \times 100$$

QUALITATIVE PHYTOCHEMICAL ANALYSIS

Alpinia galanga methanolic solvent extracts were examined for the presence or absence of the primary secondary metabolite groups using the technique described by Harborne 1998; Khandelwal 2004 [14, 15]. The extracts underwent the following assays to identify the different phytoconstituents that were present in them.

Detection of Flavonoid**Alkaline reagent Test**

To provide yellow color to 1ml of the extract solution, 1ml of 1 N NaOH solution was added. When a few drops of dilute acid are added, this color disappears, suggesting the presence of flavonoids.

Detection of Alkaloids**Dragendorff's Test**

Add 1-2 milliliters of Dragendorff's reagent to a few milliliters of filtrate. A noticeable yellow precipitate signified a positive test result.

Detection of Carbohydrates**Benedict's Tests**

Benedict's reagent (0.5 ml) was added to 0.5 ml of filtrate. The mixture was heated for two minutes in a bath of boiling water. If reducing sugars are present, a reddish-brown precipitate forms.



**Rabita and Palanisamy****Detection of Glycosides****Keller Killiani Test**

Glycosides are present in the test solution with a few drops of glacial acetic acid in 2 ml of 5% FeCl₃ and concentration H₂SO₄ from the test tube side. The upper layer, which is bluish green, and the lower layer, which is reddish brown, indicate this.

Detection of Saponins**Foam Test**

The 50 mg of extract was made into up to 20 ml by diluting it with distilled water. A graduated cylinder was used to shake the suspension for fifteen minutes. Saponins were detected by a two-centimeter layer of foam.

Detection of Tannins**Ferric chloride Test**

Five milliliters of distilled water were used to dissolve the fifty milligrams of extract. A few drops of a neutral 5% ferric chloride solution were added to this. Phenolic Compounds were identified by a dark green color.

Detection of Steroids**Salkowski Test**

After adding two milliliters of chloroform, two milliliters of test extract, and a few drops of concentrated H₂SO₄, the mixture was shaken and left to stand. The lower layer turned red, signifying the existence of sterols, and yellow, showing the presence of terpenoids.

Detection of Coumarins**NaOH Test**

By adding 1.5 ml of a 10% solution of sodium hydroxide to 1 ml of extract, coumarins can be detected by the production of a yellow color.

Detection of Quinones**Conc. HCl Test**

When 0.5 ml of con HCl is added to 1 ml of extract, quinones are present because a yellow precipitate forms.

Test for Phytosterols**Libermann-Burchard's Test**

In 2ml of acetic anhydride, the extract (50 mg) is dissolved. 1 or 2 drops of strong sulfuric acid are added to this, carefully adding them along the test tube walls. The presence of phytosterols is indicated by a variety of color changes.

Bacterial strains

Microorganisms have been obtained from the Department of Microbiology at Annamalai University. Three gram-negative strains of *Escherichia coli*, *Serratia marcescens*, and *Klebsiella pneumoniae* together with two gram-positive



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bacteria of *Bacillus subtilis* and *Staphylococcus aureus* were used in the combination. Throughout the inquiry, the bacterial cultures were used as stock cultures and were maintained at 4°C in the appropriate agar slants.

Bacterial inoculum preparation

Each test organism was grown in pure cultures, and four to five colonies were added to five milliliters of Mueller Hinton Broth (MHB). The broth was incubated for 18–24 hours at 35–37°C. To obtain 150×10^6 CFU/ml, the turbidity of the culture was compared to the 0.5 McFarland standard. In 15 to 20 minutes, the standardized inoculum suspension was inoculated [16].

Antibacterial Assay

The agar well diffusion experiment was used to quantify the zone of inhibition for various bacterial strains sensitivity to the extracts [17]. In dimethylsulfoxide (DMSO), three distinct concentrations of 25, 75, and 100 mg/mL were generated for the extracts that were going to be tested. An inoculum was collected from the standardized culture using a sterile cotton swab, and it was then inoculated on a freshly made solidified Mueller-Hinton agar and allowed to stand for approximately 15 minutes. After that, wells were made into the inoculated plates using a 6 mm sterilized stainless steel borer, and extract concentration was dispensed into the well. After allowing the plates to pre-diffusion for 15 minutes, they were incubated upright for 24 hours at 37°C. The zone of inhibition that developed around the well was later measured. DMSO as a negative control and azithromycin is used as the standard antibacterial drug. Three separate tests were conducted on the extracts and antibiotics, and mean zones of inhibition for each extract and the reference antibiotic were determined.

FT-IR Spectroscopic Analysis

The most effective instrument for classifying different kinds of chemical bonding is probably the Fourier transform infrared spectrophotometer (FT-IR) (functional groups). This annotated spectrum shows how the chemical bond is characterized by the wavelength of light absorbed. It is possible to identify a molecule chemical bond by analyzing its infrared absorption spectra. Instrumental analysis was taken into consideration for the *Alpinia galanga* plant components methanolic rhizome crude extract. Plant specimens that were pulverized were prepared for FT-IR spectroscopy (Shimadzu, IR Affinity 1, Japan). Scan range: $400\text{--}4000\text{ cm}^{-1}$ at 4 cm^{-1} resolution [18].

Statistical analysis

To reduce experimental error, each experiment was run in triplicate, and the results were given as mean \pm SD ($n = 3$). The statistical analysis was evaluated using one-way analysis of variance (ANOVA) and Duncans comparison.

RESULTS AND DISCUSSION**Percentage yield extraction**

The extractive values are helpful in estimating which specific components are soluble in which solvents and in assessing the chemical components contained in the crude medication. The yield percentage of *Alpinia galanga* extracted in methanolic solvent was 13.09%. The fiber content of the plant or sample being extracted has a significant impact on the amount of extract recovered and, in turn, the yield percentage. A very low percentage yield was obtained with high fiber concentrations. Conversely, a very high percentage yield was obtained with a low fiber concentration [26].

Preliminary Phytochemical Analysis

Table 1 summarizes the qualitative phytochemical properties of *Alpinia galanga* based on how specific chemicals cause precipitation and staining responses. *Alpinia galanga* rhizome crude extracts were evaluated by different phytochemical screening, which identified the presence of flavonoids, alkaloids, carbohydrates, tannins, saponins, phytosterols, and coumarins. However, the phytochemical testing did not identify the existence of glycosides or quinones. These substances have a wide range of possible uses in the fight against human pathogens, including those



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that result in intestinal infections [19]. Flavonoids are a diverse group of chemicals that are vital in shielding biological systems from the damaging effects of oxidative processes on macromolecules like DNA, lipids, proteins, and carbohydrates [20]. It has also been noted that saponins have hypoglycemic and anti-diabetic properties, which are highly beneficial in the treatment of diabetes mellitus. Given their well-established physiological effects, cardiac glycosides are the preferred medication for the management of congestive heart failure [21]. Tannins have the potential to have an antidiarrheal impact. They may also cause enterocyte proteins to precipitate, which would decrease intestinal secretion and peristaltic movement [22]. Steroids are highly significant substances, particularly because of their interactions with other substances like sex hormones, and it has been suggested that they have antibacterial qualities [23]. For ages, alkaloids have been used medicinally, and among their typical biological characteristics are cytotoxicity, analgesic, antispasmodic, and antibacterial effects [24]. The study findings imply that the phytochemical substances that were identified may be the bioactive components, and these plants are showing to be a useful source of bioactive chemicals with significant therapeutic value.

Antibacterial Assay

The technique of diffusion through agar wells was used to assess *Alpinia galanga* antibacterial efficacy against several pathogenic microorganisms. The *Alpinia galanga* extracts were tested for their antibacterial activity against three Gram-negative (*Klebsiella pneumoniae*, *Escherichia coli*, and *Serratia marcescens*) and two Gram-positive (*Staphylococcus aureus* and *Bacillus subtilis*) bacteria. *Alpinia galanga* methanolic rhizome crude extracts suppressed the growth of certain of the tested microorganisms to varying degrees, according to the data shown in Table 2 and Figure 1a and 1b. The studied bacteria were all found to be the most sensitive, and every extract shown efficacy against them. For gram-negative bacteria, *Escherichia coli* showed the largest (20.45 ± 1.02) zone of inhibition, while *Serratia marcescens* showed the least zone of inhibition (13.29 ± 1.17). Maximum and minimum zones of inhibition were noted for gram-positive bacteria against *Staphylococcus aureus* (19.53 ± 1.22) and *Bacillus subtilis* (12.42 ± 1.22), respectively. Since they can accomplish the same goal with less side effects that are frequently connected to synthetic antimicrobials, plant-based antimicrobials offer immense therapeutic potential [25]. Different methods allow phytochemicals to exert their antibacterial action. Consider the numerous biological actions that flavonoids possess, such as their cytostatic, antioxidant, analgesic, antibacterial, and anti-inflammatory qualities [27]. The findings additionally demonstrated the dose-dependent action of these extracts, since an increase in concentration was correlated with the zone enlargement. [28].

FT-IR Analysis

The FT-IR spectra of the methanolic rhizome extract of *Alpinia galanga* are displayed in Figure 2 and Table 3. Table 3 recorded the vibration type, intensity, and functional groupings. The FT-IR spectrum is used to determine the functional groups of the active ingredients in the extract by looking at the values of the peaks in the IR radiation band. The components functional groups were divided based on peak ratios when the extract was run through the Fourier transform infrared extractor. The functional groups viz., O-H, C-H, C=O, C=C, N-H, N-O, N-O, CO-O-CO, C-Cl, and C-H were confirmed by the FT-IR analysis results (Figure 2 and Table 3). It has been demonstrated that FTIR spectroscopy is a sensitive and dependable technique for determining the biomolecular makeup of an object. As a result, the FT-IR analysis of *Alpinia galanga* revealed novel phytochemical markers as a helpful analytical technique to assess the crude quality as well as identify the plant, which is significant for medicine.

CONCLUSION

The current study was conducted to assess *Alpinia galanga* phytochemical composition, FT-IR characteristics, and antibacterial efficacy. The significant presence of numerous essential phytochemicals throughout the rhizome of *Alpinia galanga* has been demonstrated by the qualitative phytochemical analysis. According to the FT-IR study, *Alpinia galanga* has been found to consist of essential and characteristic functional groups such as amines, carboxylic acids, alkanes, alkenes, nitro compounds, etc. These groups may be the cause of the plant many therapeutic benefits. Additionally, the plant exhibits strong antibacterial action against the particular harmful bacteria that it is targeting.





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Therefore, it is reasonable to propose that the *Alpinia galanga* rhizome has a significant medicinal value. There will be more research done to determine how the phytochemical agents and therapeutic property are related to one another. Additional research on the identification of bioactive components, determination of their effectiveness through in vivo investigations, and proof of their safety and effectiveness through clinical trials will be made easier with the use of this primary data.

REFERENCES

1. Oesper P. Biochemical systematics (Alston, Ralph E.; Turner, BL).
2. Mathai K. Nutrition in the adult years. Krause's food, nutrition, and diet therapy, 10th ed., ed. LK Mahan and S. Escott-Stump. 2000;271:274-5.
3. Hahn NI. Are phytoestrogens nature's cure for what ails us? A look at the research. Journal of the American Dietetic Association. 1998 Sep 1;98(9):974-7.
4. Rao BN. Bioactive phytochemicals in Indian foods and their potential in health promotion and disease prevention. Asia Pacific Journal of clinical nutrition. 2003 Mar 1;12(1).
5. Malik T, Pandey DK, Roy P, Okram A. Evaluation of phytochemicals, antioxidant, antibacterial and antidiabetic potential of *Alpinia galanga* and *Eryngium foetidum* plants of Manipur (India). Pharmacognosy Journal. 2016;8(5).
6. Parida R, Mohanty S, Nayak S. Evaluation of genetic fidelity of in vitro propagated greater galangal (*Alpinia galanga* L.) using DNA based markers. Int J Plant Anim Environ Sci. 2011;1(3):123-33.
7. Chudiwal AK, Jain DP, Somani RS. *Alpinia galanga* Willd.–An overview on phyto-pharmacological properties.
8. Acharya SD, Ullal SD, Padiyar S, Rao YD, Upadhyaya K, Pillai D, Raj V. Analgesic effect of extracts of *Alpinia galanga* rhizome in mice. Zhong xi yijie he xue bao= Journal of Chinese Integrative Medicine. 2011 Jan 1;9(1):100-4.
9. Kale VM, Namdeo AG. Anti-arthritis effect of 1'-Acetoxychavicol acetate in complete Freund's adjuvant induced arthritis in rats. Int. J. Pharm. Biol. Sci. 2014;5(4):9-19.
10. Jaju SB, Indurwade NH, Sakarkar DM, Fuloria NK, Ali M, Basu SP. Galangosoflavonoid isolated from rhizomes of *Alpinia galanga*. Pharmacognosy Magazine. 2009;5(19).
11. Singh YR, Kalita JC, Chandra J. Effects of Methanolic extract of *Alpinia galanga* from Manipur (India) on uterus of ovariectomised C3H albino mice. International Research Journal of Pharmacy. 2012;3(5):423-7.
12. Srividya AR, Dhanabal SP, Misra VK, Suja G. Antioxidant and antimicrobial activity of *Alpinia officinarum*. Indian journal of pharmaceutical sciences. 2010 Jan;72(1):145.
13. Srividya AR, Dhanabal SP, Satish Kumar MN, Bavadia PK. Antioxidant and antidiabetic activity of *Alpinia galanga*. International journal of Pharmacognosy and phytochemical research. 2010;3(1):6-12.
14. Harborne AJ. Phytochemical methods a guide to modern techniques of plant analysis. Springer science & business media; 1998 Apr 30.
15. Khandelwal KR. Pune: Nirali Prakashan; 2007. Practical Pharmacognosy.:149-53.
16. Saeed SA, Tariq PE. Antibacterial activities of *Mentha piperita*, *Pisum sativum* and *Momordica charantia*. Pakistan Journal of Botany. 2005 Dec 1;37(4):997.
17. Perez C. Antibiotic assay by agar-well diffusion method. Acta Biol Med Exp. 1990;15:113-5.
18. Bawaskar M, Gaikwad S, Ingle A, Rathod D, Gade A, Duran N, D Marcato P, Rai M. A new report on mycosynthesis of silver nanoparticles by *Fusarium culmorum*. Current nanoscience. 2010 Aug 1;6(4):376-80.
19. El-Mahmood AM, Doughari JH, Chanji FJ. In vitro antibacterial activities of crude extracts of *Nauclea latifolia* and *Daniella oliveri*. Sci. Res. Essay. 2008 Mar 1;3(3):102-5.
20. Atmani D, Chaher N, Atmani D, Berboucha M, Debbache N, Boudaoud H. Flavonoids in human health: from structure to biological activity. Current Nutrition & Food Science. 2009 Nov 1;5(4):225-37.





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21. Anila L, Vijayalakshmi NR. Beneficial effects of flavonoids from *Sesamum indicum*, *Emblca officinalis* and *Momordica charantia*. *Phytotherapy Research: An International Journal Devoted to Pharmacological and Toxicological Evaluation of Natural Product Derivatives*. 2000 Dec;14(8):592-5.
22. Su YL, Leung LK, Bi YR, Huang Y, Chen ZY. Antioxidant activity of flavonoids isolated from *Scutellariaehderiana*. *Journal of the American Oil Chemists' Society*. 2000 Aug;77(8):807-13.
23. Okwu DE. Evaluation of chemical composition of medicinal plants belonging to Euphorbiaceae. *Pak Vet J*. 2001;14:160-2.
24. Aiyegoro OA, Okoh AI. Preliminary phytochemical screening and in vitro antioxidant activities of the aqueous extract of *Helichrysum longifolium* DC. *BMC complementary and Alternative Medicine*. 2010 Dec;10:1-8.
25. Iwu MW, Duncan AR, Okunji CO. New antimicrobials of plant origin. Perspectives on new crops and new uses. ASHS Press, Alexandria, VA. 1999;457:462.
26. Ukwuani AN, Igbokwu MO. In vitro antidiabetic effect of *Leptadeniahastata* leaves fractions. *Biosciences Research in Today's World*. 2015;1(1):40-6.
27. Maikai VA, Maikai BV, Kobo PI. Antimicrobial properties of stem bark extracts of *Ximenia americana*. *Journal of Agricultural Science*. 2009 Dec 1;1(2):30.
28. Karga T, Venkatesan A. Qualitative Phytochemical Analysis, In Vitro Antioxidant Activities and Antimicrobial Assessment of Methanolic Leaf, Root and Stem Extracts of *Rhizophora apiculata*.

Table 1: Qualitative Phytochemical Analysis of *Alpinia galanga*

Sl. No.	Phytochemical Test	Name of the Test	Methanolic Extract of <i>A. galanga</i>
1.	Flavonoid	Alkaline reagent Test	+
2.	Alkaloids	Dragendorff's Test	+
3.	Carbohydrates	Benedict's Test	+
4.	Glycosides	Keller Killani Test	-
5.	Saponins	Foam Test	+
6.	Tannins	Ferric chloride Test	+
7.	Steroids	Salkowski Test	+
8.	Coumarins	NaOH Test	+
9.	Quinones	Conc. HCl Test	-
10.	Phytosterols	Libermann-Burchard's Test	+

(+) indicate present, (-) indicate absent, *A. galanga* = *Alpinia galanga*

Table 2: Antibacterial activity of *Alpinia galanga* showing zone of inhibition.

Sl. No.	Bacterial Strains	Experimental Unit	Zone of inhibition (mm) mean ± SD
Gram-negative Bacteria			
1.	<i>Serratia marcescens</i>	K ₁	13.29±1.17
		K ₂	15.48±0.76
		K ₃	17.41±1.26
		PC	18.76±0.82
		NC	0
2.	<i>Escherichia coli</i>	K ₁	15.96±0.72
		K ₂	18.37±1.17
		K ₃	20.45±1.02
		PC	22.35±1.17
		NC	0
3.	<i>Klebsiella pneumoniae</i>	K ₁	14.39±1.05
		K ₂	16.37±1.04





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		K ₃	18.34±0.88
		PC	20.39±0.98
		NC	
Gram-positive Bacteria			
4.	<i>Bacillus subtilis</i>	K ₁	12.42±1.22
		K ₂	14.41±0.97
		K ₃	16.47±0.89
		PC	18.46±1.09
		NC	0
5.	<i>Staphylococcus aureus</i>	K ₁	15.60±1.42
		K ₂	17.35±1.02
		K ₃	19.53±1.22
		PC	21.33±1.06
		NC	0

K1=25%, K2=75%, K3=100%, PC=Positive Control and NC= Negative Control

Table 3: FT-IR Analysis of *Alpinia galanga* methanolic rhizome crude extract

Sl. No.	Frequency (Cm ⁻¹)	Absorption Intensity	Vibration type	Band Assignment	Type of Compounds
1.	3268.9	Strong, Broad	Stretching	O-H	Alcohol
2.	2926.0	Medium	Stretching	C-H	Alkane
3.	1718.3	Strong	Stretching	C=O	Aliphatic ketone
4.	1591.6	Medium	Bending	N-H	Amine
5.	1509.6	Strong	Stretching	N-O	Nitro compound
6.	1405.2	Medium	Bending	O-H	Carboxylic acid
7.	1367.9	Medium	Bending	O-H	Phenol
8.	1230.0	Medium	Stretching	C-N	Amine
9.	1043.7	Strong, Broad	Stretching	CO-O-CO	Anhydride
10.	924.4	Strong	Bending	C=C	Alkene
11.	820.2	Strong	Stretching	C-Cl	halo compound
12.	775.3	Strong	Bending	C-H	1,2-disubstituted

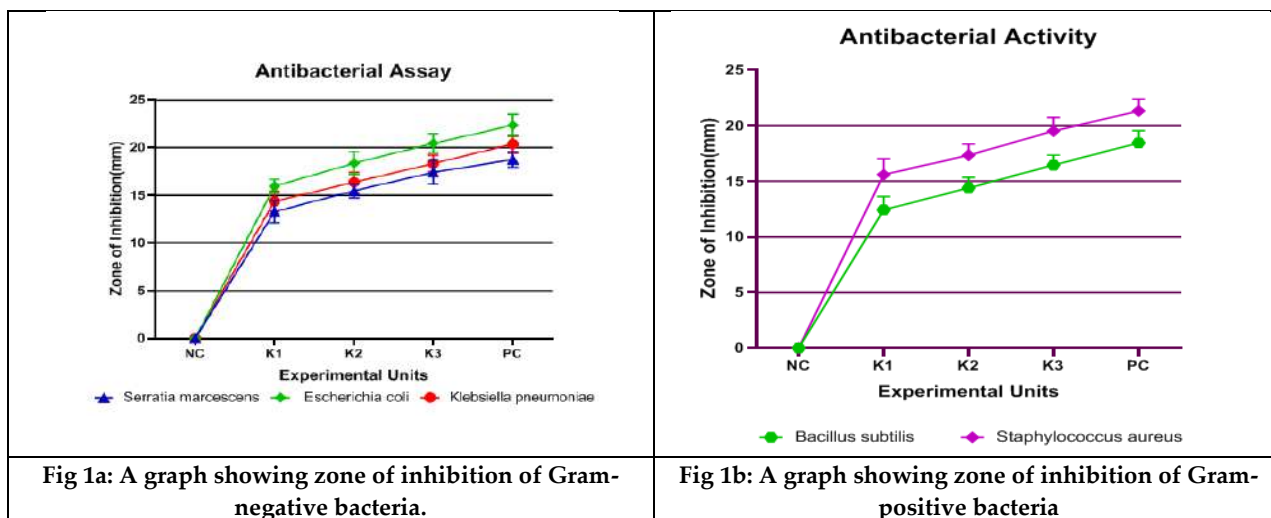


Fig 1a: A graph showing zone of inhibition of Gram-negative bacteria.

Fig 1b: A graph showing zone of inhibition of Gram-positive bacteria





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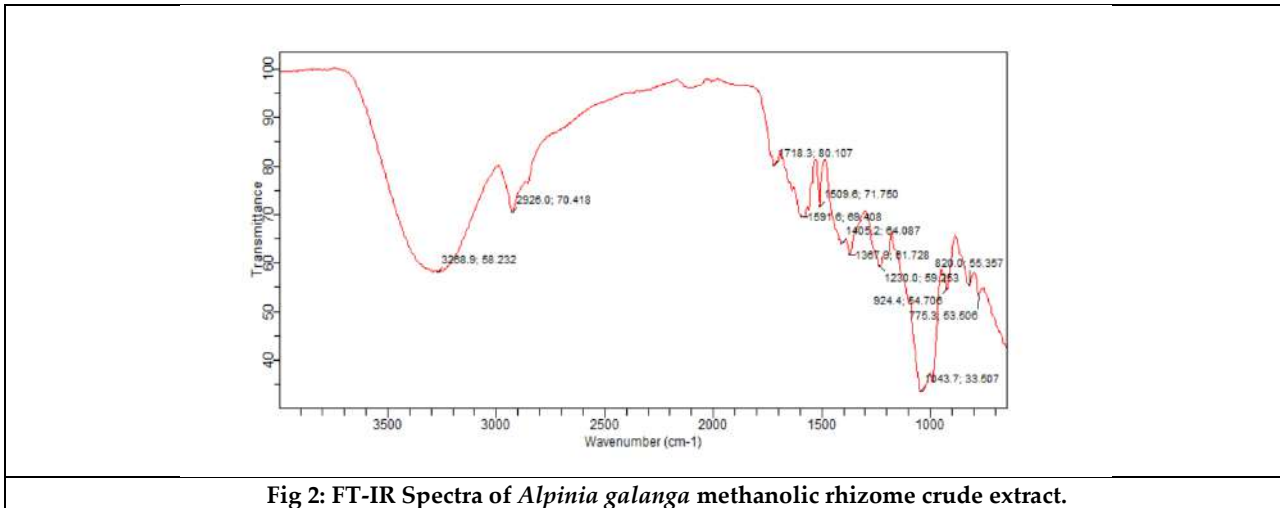


Fig 2: FT-IR Spectra of *Alpinia galanga* methanolic rhizome crude extract.





Crop Species for Heavy Metal Phytoremediation at the Yadavagiri Industrial Area, Mysuru, India

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ABSTRACT

The two main barriers to a successful phytoremediation program are the availability of metal in the soil and the absorption and transfer of metal to the shoots of high-biomass plants. Multiple approaches have been studied to improve the metals' bioavailability in soil and accumulation in plants; in this work, phytoremediation techniques were employed. The phytoremediation of Cd, Zn, and Ni by *Lactuca Sativa* L. and *Sorghum bicolor* L. reduces the metal toxicity in soil. For the eighty days that the treatments were conducted, two plants were grown on soil that had been taken from the Yadavagiri study area. Five soil samples contaminated which used for this study. The outcomes demonstrated that the metal toxicity in the polluted soil might be reduced, increasing shoot biomass and perhaps improving the efficiency of phytoextraction. One of the most important aspects of efficient phytoextraction is the increased concentration of metals in shoots, which strengthens the potential of Cd to translocate to shoots in the contaminated soil. Conversely, there was decreased absorption and concentration of zinc and nickel in the roots and shoots. Thus, phytoremediation concerning these two plants was examined in the present study.

Keywords: *Lactuca sativa* L, Bioaccumulation, Heavy Metals, *Sorghum bicolor* L, translocation.



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INTRODUCTION

As a result of industrial growth in many nations, heavy metal pollution is currently one of the major environmental problems. Heavy metals have harmful impacts on human health and are the primary cause of many chronic illnesses[1]. Since heavy metals cannot be reduced by degradation, they constitute a bigger worry than other environmental pollutants. To remove heavy metals from polluted places, certain approaches must be used in the remediation process of contaminated soils, groundwater, and surface water[2]. Phytoremediation is a more ecologically friendly, economical, and environmentally friendly option when compared to conventional physical and chemical treatment approaches[3]. Phytoremediation is a new term, that has been used since 1991. The Latin word *remedium*, which means "to correct or remove evil," and the Greek prefix *phyto*, which means "plant," combine to form the term "phytoremediation." Basic data for phytoremediation is derived from several study fields, such as artificial wetlands, oil spills, and heavy metal buildup in agricultural plants. Since its introduction, the phrase has been extensively used and has been associated with several distinct meanings. Plants have a variety of ways to remove heavy metal pollution from the environment. Six plant processes are involved in the phytoremediation process, which removes contaminants from soils they are phytodegradation, phytoextraction, phytovolatilation, phytostabilisation, rhizodegradation, and phytofiltration[4,5]. The metals including As, Cd, Cr, and Pb are mostly linked to phytotoxicity because they have lower values for hyperaccumulation (particularly for Cd) and very low toxicity thresholds when compared to the other metals[6]. *Lactuca sativa* has great flavour and high nutritional content, lettuce is one of the most popular green leafy vegetables that are grown all over the world and consumed fresh. It is thought to be a significant phytonutrient source. Significant physical and genetic differences define it.

The Egyptians were the ones who invented this leafy vegetable. It is currently produced all over the world and used in forensic medicine to treat a wide range of illnesses, including urinary tract infections, discomfort, and stomach and inflammatory issues. Its pharmacological potential, including antibacterial, antioxidant, neuroprotective, and hypnotic actions, has been scientifically demonstrated by several research[7]. Several research found that this plant has the phytoremediation capacity to degrade Cu, Zn, and Cd heavy minerals from soil[7-14]. Sorghum, or sorghum bicolor (L.), is one of the top five cereal crops in the world. It is the primary diet of billions of people and is essential to the global food supply. Sorghum is a valuable crop that is used for broomcorn, sweet stem, and grain. It also generates gasoline, bioethanol, building materials, and alcoholic beverages. In wealthier countries, it is mostly grown for animal feed and fodder, but in dry and semi-arid regions of the world, it is one of the most important food crops[15-17]. This plant has an effective phytoremediation capacity to degrade Cu, Zn, and Cd heavy minerals from soil [18-21]. To evaluate the growth conditions and the phytoremediation ability of *Lactuca sativa* L. and *Sorghum bicolor* L., this study assessed the transfer of metals from the soil into the root and shoot systems of the two grown plants.

MATERIALS AND METHODS

Study Area

The study area is situated in Yadavagiri Industrial Area, Karnataka, India. Areas are irrigated with industrially contaminated wastewater. Most of the industries in this area are near bodies of water, which can spread their toxins to nearby bodies of water and pollute the surrounding land with heavy metals.

Experimental setup

The two plant genotypes used in the experiment were bought from the Mysuru, Karnataka, local seed market. A typical irrigated region in Mysuru City was used to collect the heavy metal levels in the soil polluted by industrial wastewater, the control soil, and the control crops. In the agriculture field, ten pieces of 4 × 5 meters each were formed. After being planted 30 cm below the surface and spaced 30 cm apart from one another, the seeds were left to develop for 80 days before samples were collected when they were ready to be harvested. As soon as the plants





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were picked, fresh weight measurements were taken, and after two days of oven drying at 50 °C, dry weight measurements were taken.

Sample collection and its preparation

Per square meter in the field, the quantity and weight of producing plants for each treatment were noted. Ten plant heights were examined. After taking careful action to remove all dirt and debris, the samples were separated into shoots and roots, washed with distilled water, and then securely kept in bags. To represent it, three copies of each plant sample were employed. Every soil sample was obtained in three duplicates, and the samples were taken from 0 to 30 cm below the surface. Before examination, soil samples were allowed to dry, lightly crushed, and then sieved through to a 2 mm size. The plant samples were digested with a tri-acid combination and their pH was measured. Two millilitres of aqua regia were added to the preserved digested sample, and the samples were then kept in a 100-millilitre distilled container. Through the use of ICPAES (Inductively Coupled Plasma Atomic Emission Spectroscopy) techniques, the quantity of heavy metals in the digested sample was determined.

Calculation formulas

Planting season remediation (%) = Remedial metal fraction/initial concentration of metals in the soil before planting × 100. Remediated metal fraction (mg/kg) is the difference between the initial and final metal concentrations in the soil before and following planting[22]. Bioconcentration Factor-BCF (Shoots or roots) = Concentration of metal in parts of the plant (shoots or roots) / metal concentration in soil Translocation Factor = Metal concentration in stems and leaves /Metal concentration in roots[23,24].

RESULTS AND DISCUSSIONS

The five soil samples were collected from the study area on that soil where the plant was grown for 80 days five plant samples were examined from each plant. The minimum, maximum, and Mean of all samples were discussed.

Assessment of heavy metals concentration by *Lactuca sativa* L

The concentrations of the heavy metals Cd, Zn, and Ni in soil and plant parts were measured and recorded in Tables 3.1, 3.2, and 3.3. The Cd concentration in soil was 9.39 mg/kg, Zn concentration was 157.25 mg/kg, and Ni was 89.23 mg/kg. Referring to Table 3.1, the Cd concentrations in the samples of shoots and roots varied between 0.21 to 0.39 (mean of 0.30 mg/kg) and 1.02 to 1.10(mean of 2.71 mg/kg) respectively. the Cd concentrations in the soil samples were significantly lower, mean of 5.65mg/kg, within the 5.12–5.65 range. The Cd remediated fraction represented, varied from 3.21 to 4.27 with a mean of 3.74. The remediation percentage ranged from 34.19% to 45.47% a mean 39.83 %. The bioconcentration factor varied between 0.21-0.35 (mean 0.11 mg/kg) in shoots and between 0.11-0.12 (mean 0.28 mg/kg) in roots. The translocation factor varied from 0.21 to 0.35 with a mean of 0.11mg/kg. Zn concentrations in shoot samples varied between 1.18 to 1.38(mean of 1.28 mg/kg) and in root, samples varied between 5.65 to 6.12(mean of 5.88 mg/kg) as shown in Table 3.2. The concentrations of Zn in the soil samples were significantly lower, mean of 156.24mg/kg, within the 155.23–157.23 range. The Zn remediated fraction represented, varied from 13.04 to 15.06 with a mean of 8.23. Remediation percentage ranged from 7.66% to 8.84% with a mean of 8.23 %. The bioconcentration factor varied between 0.21-0.23 (mean 0.22 mg/kg) in shoots and between 0.03-0.04 (mean 0.03 mg/kg) in roots. The translocation factor varied from 0.21-0.23 with a mean of 0.22mg/kg. Ni concentrations in shoot samples varied between 2.22 to 4.56(mean 3.18 mg/kg) and in the root, samples varied between 12.12 to 18.58(mean 15.01 mg/kg) according to (Table 3.3). The concentrations of Ni in the soil samples were significantly lower, mean of 66.34mg/kg, within the 65.12–67.58 range. The Ni remediated fraction represented, varied from 21.65 to 24.11 with a mean of 22.85. Remediation percentage ranged varied between 24.26% to 27.02% (mean of 25.60%). The bioconcentration factor varied between 0.18-0.25(mean 0.21 mg/kg) in shoots and between 0.18-0.21 (mean 0.17 mg/kg) in roots. The translocation factor varied from 0.18-0.25 with a mean of 0.21mg/kg.



**Santhosh M Sosale and Raju****Assessment of heavy metals concentration by Sorghumbi color L**

The same soil which was randomly collected at Yadavagiri industrial area in 5 locations same soil was used to assess the phytoremediation of plants. Even here the heavy minerals Cd, Zn, and Ni were remediated by plants shown in tables 3.4, 3.5, and 3.6. Referring to Table 3.4, the Cd concentrations in the samples of shoots and roots varied between 0.16 to 0.25 (mean of 0.20 mg/kg) and 1.10 to 1.19 (mean of 1.14 mg/kg) respectively. The Cd concentrations in the soil samples were significantly lower, mean of 6.17 mg/kg, within the 6.12–6.23 range. The Cd remediated fraction represented, varied from 3.16 to 3.27 with a mean of 3.21. The remediation percentage ranged from 33.65% to 34.82% a mean 34.23 %. The bioconcentration factor varied between 0.15–0.21 (mean 0.17 mg/kg) in shoots and between 0.12–0.13 (mean 0.12 mg/kg) in roots. The translocation factor varied from 0.15–0.21 with a mean of 0.17 mg/kg. Zn concentrations in shoot samples varied between 0.98 to 1.19 (mean of 1.08 mg/kg) and in the root, samples varied between 6.71 to 7.14 (mean of 6.92 mg/kg) as shown in Table 3.5. The concentrations of Zn in the soil samples were significantly lower, mean of 153.74 mg/kg, within the 152.23–155.27 range. The Zn remediated fraction represented, varied from 15.02 to 18.06 with a mean of 16.47. Remediation percentage ranged from 8.82% to 10.61% with a mean of 9.67 %. The bioconcentration factor varied between 0.15–0.17 (mean 0.16 mg/kg) in shoots minimum, and maximum, and the mean was 0.04 mg/kg in roots. The translocation factor varied from 0.15–0.17 with a mean of 0.16 mg/kg. Ni concentrations in shoot samples varied between 3.12 to 4.25 (mean 3.64 mg/kg) and in the root, samples varied between 14.15 to 16.25 (mean 15.16 mg/kg) according to (Table 3.6). The concentrations of Ni in the soil samples were significantly lower, mean of 61.58 mg/kg, within the 60.21–62.98 range. The Ni remediated fraction represented, varied from 26.25 to 29.02 with a mean of 27.60 mg/kg. Remediation percentage ranged varied between 29.42% to 32.52% (mean of 30.93%). The bioconcentration factor varied between 0.22–0.26 (mean 0.24 mg/kg) in shoots and between 0.16–0.18 (mean 0.17 mg/kg) in roots. The translocation factor varied from 0.22 to 0.26 with a mean of 0.24 mg/kg.

CONCLUSION

We evaluated the feasibility of *Lactuca sativa* L. and *Sorghum bicolor* L. plants cultivated on soil polluted by industrial activities to promote plant development and phytoremediation of Cd, Zn, and Ni. According to our findings, the Cd remediate percentage and Translocation factor were higher by *Lactuca sativa* L when compared with *Sorghum bicolor* L plant. In the polluted soil, sorghum has a good phytoextractor in the case of Zn. The Ni remediate percentage and Translocation were higher by plant *Sorghum bicolor* L. In context of the remediation percentage Cd>Ni>Zn by both the plant *Lactuca sativa* L and *Sorghum bicolor* L which was cultivated at 80 days on soil which was collected from Yadavagiri, Mysuru at Karnataka.

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Conflict of Interest

There was no potential conflict of interest by the author.





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REFERENCES

1. A Sumiahadi and R Acar, A review of phytoremediation technology: heavy metals uptake by plants, 2018, *IOP Conf. Ser.: Earth Environ. Sci.* **142** 012023.
2. Henry J R 2000 An Overview of the Phytoremediation of Lead and Mercury (Washington : US Environmental Protection Agency).
3. Ashraf, S., Ali, Q., Zahir, Z. A., Ashraf, S., &Asghar, H. N. (2019). Phytoremediation: Environmentally sustainable way for reclamation of heavy metal polluted soils. *Ecotoxicology and Environmental Safety*, 174, 714-727.
4. Ali H, Khan E and Sajad M A 2013 Phytoremediation of heavy metals – concepts and applications *Chemosphere* 91 869-81.
5. Dixit R, Wasiulah, Malaviya D, Pandiyan K, Singh U B, Sahu A, Shukla R, Singh B P, Rai J P, Sharma P K, Lade H and Paul D 2015 Bioremediation of heavy metals from soil and aquatic environment: An overview of principles and criteria of fundamental processes *Sustainability* 7 2189-212.
6. Clemens, 2006, Toxic metal accumulation, responses to exposure and mechanisms of tolerance in plants. *Biochimie*. 88,1707-1719.
7. Noumedem, Jaurès&Djeussi, Doriane&Hritcu, Lucian & Marius, Mihasan&Kuete, Victor, 2017, Medicinal Spices and Vegetables from Africa, 437-449.
8. Musa, Dahiru&Garba, Yusuf & Yusuf, M &Danjuma Sani, Mahadi. (2017). POTENTIAL OF LETTUCE(LATUCA SATIVA) FOR PHYTOREMEDIATION OF Cd, Cu, Cr AND Pb IN CONTAMINATED SOIL ALONG RIVER SALANTA. *Dutse Journal of pure and Applied Sciences*. 3. 258 - 269.
9. Zhao, Jun; Lu, Cong; Tariq, Muhammad; Xiao, Qinran; Zhang, Wei; Huang, Kai; Lu, Qiang; Lin, Kuangfei; Liu, Zaochang (2019). The response and tolerance mechanisms of lettuce (*Lactuca sativa* L.) exposed to nickel in a spiked soil system. *Chemosphere*, 222, 399–406.
10. Ikkonen E, Kaznina N. Physiological Responses of Lettuce (*Lactuca sativa* L.) to Soil Contamination with Pb. *Horticulturae*. 2022; 8(10):951.
11. Quainoo AK, Konadu A, Kumi M (2015) The Potential of Shea Nut Shells in Phytoremediation of Heavy Metals in Contaminated Soil Using Lettuce (*Lactucasativa*) as a Test Crop. *J BioremedBiodeg* 5:268.
12. Manar M Morsy, Mona I Nossier, Abd-Ellatif S El-Sebaay, Shaimaa H Abd-Elrahman, Phytoremediation of Pb and Cd by Alfalfa (*Medicagosativa* L.): an Applied Study in the Presence of Lettuce Plants (*Lactuca sativa* L.), *Arab Univ J AgricSci* (2022) 30 (1) 163-174.
13. J. D. O. Santosa, E.S. Silvaa, P. Silvaa, M. A. C. Silvaa, L. A. Santosa, A. F. Santosb,c, T. J. Matos-Rochab,d, J. M. S. J. Pavãob, A Physiological behavior and tolerance of *Lactucasativa* to lead nitrate and silver nitrate heavy metals, *Brazilian Journal of Biology*, 2022, 82, e237604.
14. Hala H. Gomah, Mohamed M. M. Ahmed, Reham M. Abdalla, Khaled A. Farghly & Mamdouh A. Eissa (2020) Utilization of some organic wastes as growing media for lettuce (*Lactuca sativa* L.) plants, *Journal of Plant Nutrition*, 43:14, 2092-2105.
15. Mace, E. S., Rami, J. F., Bouchet, S., Klein, P. E., Klein, R. R., Kilian, A., et al. (2009). A consensus genetic map of sorghum that integrates multiple component maps and high-throughput Diversity Array Technology (DArT) markers. (Research article)(Report). *BMC Plant Biol.* 9, 13.
16. Venkateswaran, K., Muraya, M., Dwivedi, S. L., Upadhyaya, H. D. (2014). "Wild sorghums-Their potential use in crop improvement", in *Genetics, genomics and breeding of sorghum*. Eds. Wang, Y., Upadhyaya, H. D., Chittaranjan, K. (Florida, USA: CRC Press), 78–111.
17. Hariprasanna, K., Patil, J. V. (2015). "Sorghum: Origin, classification, biology and improvement," in *Sorghum molecular breeding*. Eds. Madhusudhana, R., Rajendrakumar, P., Patil, J. V. (New Delhi, India: Springer), 3–20.
18. Osman HE, Fadhlallah RS, Alamoudi WM, Eid EM, Abdelhafez AA. Phytoremediation Potential of Sorghum as a Bioenergy Crop in Pb-Amendment Soil. *Sustainability*. 2023; 15(3):2178.





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19. Xiao, MZ., Sun, Q., Hong, S. *et al.* Sweet sorghum for phytoremediation and bioethanol production. *J Leather SciEng* 3, 32 (2021).
20. Oh, K., Cao, T.H., Cheng, H.Y., Liang, X.H., Hu, X.F., Yan, L.J., Yonemochi, S. and Takahi, S. (2015) Phytoremediation Potential of Sorghum as a Biofuel Crop and the Enhancement Effects with Microbe Inoculation in Heavy Metal Contaminated Soil. *Journal of Biosciences and Medicines*, 3, 9-14.
21. Gorelova, S.V., Kolbas, A.P., Muratova, A.Y., Frontasyeva, M.V., Zinicovscaia, I., Okina, O.I. (2023). Prospects for the Use of *Sorghum Bicolor* for Phytoremediation of Soils Contaminated with Heavy Metals in Temperate Climates. In: Newman, L., Ansari, A.A., Gill, S.S., Naem, M., Gill, R. (eds) *Phytoremediation*. Springer, Cham, 263–301.
22. Shumo MI, Taha KK, Ahemad AY, Hamid HB, Abdullah MP, Digestion with HNO₃/H₂O₂ mixture for determination of trace elements in sediment using inductively coupled plasma-mass spectrometry. *J ApplIndustri Sci*. 2014; 2:85–92
23. Shehata, S.M., Badawy, R.K. &Aboulsoud, Y.I.E. Phytoremediation of some heavy metals in contaminated soil. *Bull Natl Res Cent*. 2019; 43:189
24. Nizam UM, U-Zzaman W, Rahman MM, Kim JE, Phytoremediation potential of kenaf (*Hibiscus cannabinus* L.), mesta (*Hibiscus sabdariffa* L.), and jute (*Corchoruscapsularis* L.) in arsenic-contaminated soil. *Korean J Environ Agric*.2016; 35:111–120.

Table 1: Total mg/kg of Cd contained in soil and plant parts.

Sample	Shoot	Root	Initial value of soil	Soil value after planting	Remediated fraction	Remediation Percentage	BCF shoot	BCF root	TF
Minimum	0.21	1.02	9.39	6.18	3.21	34.19	0.21	0.11	0.21
Maximum	0.39	1.10	9.39	5.12	4.27	45.47	0.35	0.12	0.35
Mean	0.30	2.71	9.39	5.65	3.74	39.83	0.11	0.29	0.11

Table 2: Total mg/kg of Zn contained in soil and plant parts.

Sample	Shoot	Root	Initial value of soil	Soil value after planting	Remediated fraction	Remediation Percentage	BCF shoot	BCF root	TF
Minimum	1.18	5.65	170.29	157.25	13.04	7.66	0.21	0.03	0.21
Maximum	1.38	6.12	170.29	155.23	15.06	8.84	0.23	0.04	0.23
Mean	1.28	5.88	170.29	156.24	14.01	8.23	0.22	0.03	0.22

Table 3: Total mg/kg of Ni contained in soil and plant parts.

Sample	Shoot	Root	Initial value soil	Soil value after planting	Remediated fraction	Remediation Percentage	BCF shoot	BCF root	TF
Minimum	2.22	12.12	89.23	67.58	21.65	24.26	0.18	0.14	0.18
Maximum	4.56	18.58	89.23	65.12	24.11	27.02	0.25	0.21	0.25
Mean	3.18	15.01	89.23	66.34	22.85	25.60	0.21	0.17	0.21

Table 4: Total mg/kg of Cd contained in soil and plant parts

Sample	Shoot	Root	Initial value soil	Soil value after planting	Remediated fraction	Remediation Percentage	BCF shoot	BCF root	TF
Minimum	0.16	1.10	9.39	6.23	3.16	33.65	0.15	0.12	0.15
Maximum	0.25	1.19	9.39	6.12	3.27	34.82	0.21	0.13	0.21
Mean	0.20	1.14	9.39	6.17	3.21	34.23	0.17	0.12	0.17





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Table 5: Total mg/kg of Zn contained in soil and plant parts

Sample	Shoot	Root	Initial value soil	Soil value after planting	Remediated fraction	Remediation Percentage	BCF shoot	BCF root	TF
Minimum	0.98	6.71	170.29	155.27	15.02	8.82	0.15	0.04	0.15
Maximum	1.19	7.14	170.29	152.23	18.06	10.61	0.17	0.04	0.17
Mean	1.08	6.92	170.29	153.74	16.47	9.67	0.16	0.04	0.16

Table 6: Total mg/kg of Ni contained in soil and plant parts.

Sample	Shoot	Root	Initial value soil	Soil value after planting	Remediated fraction	Remediation Percentage	BCF shoot	BCF root	TF
Minimum	3.12	14.15	89.23	62.98	26.25	29.42	0.22	0.16	0.22
Maximum	4.25	16.25	89.23	60.21	29.02	32.52	0.26	0.18	0.26
Mean	3.64	15.16	89.23	61.58	27.60	30.93	0.24	0.17	0.24





A Compressive Review: Mechanisms Underlying the use of Diuretics in the Treatment of Hypertension

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ABSTRACT

For a long time, diuretics have been used to treat hypertension. An oral diuretic has been the most often prescribed first-line treatment for hypertension in the United States for more than 15 years. Diuretics have many of the features of an ideal step-one drug they're inexpensive, simple to titrate, productive in a large majority of low to medium hypertension patients, well tolerated, and the effective of other antihypertensive drugs. Although thiazide diuretics are among the most usually given diuretics for high blood pressure, in some circumstances, alternative types of diuretics may be more beneficial. While diuretics aren't any longer the recommended treatment for children and adults with hypertension, they are still effective first-line alternatives. Diuretics lower blood pressure in hypertensive people and cut the chance of developing cardiovascular events in adults with hypertension significantly. Chlorthalidone could be the preferable thiazide diuretic in the management of hypertension due to pharmacokinetic and pharmacodynamic differences. Diuretics have recently sparked concerns regarding their safety. In all of the controlled trials of placebo that indicated a decline in cardiovascular morbidity and mortality, an oral diuretic was used as the first step. Diuretics have more favourable qualities than any other alternative for step-one antihypertensive therapy. Less dose of diuretics should remain the first treatment for most hypertension patients unless another antihypertensive medication is prescribed. Other types of diuretics, such as potassium sparing diuretics and loop diuretics, may be helpful in the treatment of hypertension



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caused by CKD and other disorders. Electrolyte and metabolic issues are the most common thiazide side effects, which are dose-dependent.

Keywords: Hypertension, diuretics, thiazide diuretics, treatment, side effects

INTRODUCTION

Hypertension treatment using a plan which is diuretic-based is shown to help prevent stroke and heart illness in randomized clinical studies, along with a consistent "track record" that continues to this day, as noted in ALLHAT.¹ A conventional two combination comprising a thiazide-type diuretic and either ACE inhibitor or an α -blocker, both given once per day, can hold a large percentage of all hypertensives, particularly African and American hypertensives. The cost is low, the control rate is high, and drug adherence is almost perfect. There is a strong case to be made that thiazide-type diuretics should be employed as the first line of therapy for all hypertension patients.² A secondary issue with that reasoning is that chlorthalidone and other thiazides have no discernible difference.^{3,4} Diuretics, on the other hand, are not a single medication class, but rather three separate sub-classes, each of which has a vital role in the care of most hypertension patients. Even though often diuretics are in clinical use for a long time, new medications in this category have been developed. The 3 major types of diuretics that are utilized to treating hypertension. will be discussed: loop-active medications, thiazide-type and potassium-sparing treatments, all of which act as inhibitors of the epithelial sodium channel or mineralocorticoid antagonists in the end distal renal tubule. Carbonic anhydrase inhibitors are a separate type of medicine that isn't used to treat high blood pressure.⁵

Classification of Antihypertensives

Classification of antihypertensives is presented in the Figure 1.^{6,7}

Mode of action of antihypertensive drugs

Site of action of various antihypertensive drugs is presented in Figure 2.⁸

Classification of DIURETICS

Classification of Diuretics is presented in Figure 3

THIAZIDE-TYPE DIURETICS

Hydrochlorothiazide and its numerous variations reduce blood pressure as single therapy combination with ACE inhibitors or AT1 blockers, β -blockers. The use of a thiazide-type diuretic as the first line of treatment for all hypertensives is still debatable. The SHEP study emphasises the need of using a lower dose of thiazide-like drug as the primary treatment for systolic hypertensive elderly patients as well as ALLHAT clearly favours this decision for African-American patients with hypertension.⁹ People who have actually tried a beta-blocker or an ACE inhibitor but still have high blood pressure may benefit from a diuretic.¹⁰ In either case, most hypertensives treated with one of these two drug combinations will have their blood pressure under control. A baseline serum electrolyte measurement and serum potassium monitoring are required when using a thiazide-type medication. As a result of diuretic-induced hyperuricemia, gout is still a rare side effect, and hypercalcemia is also a possibility. These side effects are caused by thiazide-induced decreases urate in urine and excretion of calcium. As well as type 2 diabetes can occur while taking thiazide-type diuretics, there appears to be minimal enhancement of cardiovascular events in senior people in comparison to those who already have diabetes. Patients receiving low-dose thiazide-type diuretics who experience hypokalemia may be diagnosed with primary aldosteronism. Spironolactone, eplerenone, or amiloride, as well as other potassium-sparing medicines, may be used to effectively control high blood pressure and without a full clinical examination or the potential of adrenal ectomy, you can treat hypokalemia. Surgical treatment for primary aldosteronism has not been proven to be superior to effective medical management in any study Figure 4.^{11,12}



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The ineffectiveness of hydrochlorothiazide compared to thiazide-like drugs and else antihypertensive medicines is being examined un depth.¹³⁻¹⁵ Hydrochlorothiazide differs from thiazide-like diuretics in terms of structure and mechanism of action. hydrochlorothiazide has a shorter half-life than chlorthalidone, beta blockers, ACE inhibitors, indapamide, angiotensin receptor blockers, beta blockers and calcium channel blockers, and is less potent by 4.2-6.2 mm Hg SBP than ACE inhibitors, AT1 blockers, beta blockers, and CCB. In circuit assessments of trials, hydrochlorothiazide was considered lower in limiting CVEs in the ANBP2 trial than amlodipine, enalapril, chlorthalidone, and hydrochlorothiazide-amiloride, and in the accomplish trial than chlorthalidone and hydrochlorothiazide-amiloride. Gout and hypokalemia have been shown to be caused by hydrochlorothiazide in the same way that chlorthalidone does. In hypertensive and diabetic patients, hydrochlorothiazide is now less efficient than indapamide at increasing endothelial function and longitudinal strain.¹⁶ In terms of enhancing coronary flow reserve, hydrochlorothiazide is less effective than SPIR. Despite these findings, fifty million prescriptions (excluding set combos) in 2013, hydrochlorothiazide was indeed the twelfth most commonly given drug in the United States in 2013, and it's mystifying that there would never be a placebo-controlled trial examining its usefulness in lowering CVEs. However, it's worth noting that studies have indicated that hydrochlorothiazide-triamterene and hydrochlorothiazide-amiloride are more effective than placebo at lowering CVEs. (In contrast to a recent meta-analysis, we consider these preparations as different from hydrochlorothiazide itself), the justification for potassium-sparing combinations is compelling. In passing, we should mention that, at standard doses, there is no specific link between a diuretic's serum half-life and its biologic efficacy that is independent of the diuretic's basic effect. The fact that one of these medications has a longer serum half-life is irrelevant unless the obtained concentration remains above the drug effect threshold. Furthermore, NSAID medicines, that inhibit vasodilatory prostaglandin formation and hence impact negatively renal salt processing, can reduce the antihypertensive action of thiazide-related diuretics when taken together.^{17,18}

LOOP-ACTIVE DIURETICS

When chronic renal disease progresses from phase 3 to 5, especially when volume of extracellular fluid expands, loop diuretic treatment will become the predominant diuretic therapy for the control of hypertension. Multiple loop diuretics reduce Systolic/diastolic BP in primary hypertension, according to a new Cochrane study., loop diuretics are less efficient than thiazide-like medicines in lowering BP in the non-edematous patient.¹⁹ There was no difference among the multiple loop diuretics reported in this Cochrane review, and the evidentiary reliability was inadequate, with a more chance of biasness of publications. Low-dose loop torasemide has an antihypertensive effect that improves with time.²⁰ Furosemide and its analogues (torsemide or bumetanide) block Na^+ , K^+ , Ca^{2+} resorption in the distal renal tubule at sites other than the thiazide-sensitive loci in the ascending limb of the loop of Henle. These loop-active drugs have a brief duration of action and must be administered twice daily to treat hypertension. Renal insufficiency lessens the efficiency of thiazide-like diuretics., as measured by lower creatinine clearance. Despite renal impairment, furosemide is remarkably efficient, albeit large doses are typically required as serum creatinine rises. Hypokalemia can be caused by loop-active diuretics, which could be treated with potassium-sparing diuretics or potassium supplementation. In these conditions, careful monitoring of serum potassium is required. Loop-active diuretics, unlike thiazide-type medicines, promote Ca^{2+} elimination and can lower serum Ca^{2+} as a therapy for hypercalcemia.²¹ A schematic diagram of loop-active diuretics is shown in **Figure 5** and **Figure 6**.

POTASSIUM-SPARING DIURETICS

Potassium-sparing diuretics are much more helpful in controlling blood and intracellular potassium levels than potassium supplementation. Observational and randomised trial studies have depicted that thiazide and thiazide-type diuretics (at high dosages) can cause ventricular ectopy and death, and that potassium-sparing diuretics can help prevent this. When compared to placebo, eplerenone, spironolactone, amiloride, and triamterene have all been effective, while the former two have been used with hydrochlorothiazide to reduce CVEs. In the treatment of sensitive hypertension, both spironolactone and amiloride (up to 10 mg and in conjunction with hydrochlorothiazide) have been proven to be beneficial.²² The dose of these medications is elucidated by a recent meta-analysis of 44 studies, which may encourage the usage of neglected agents Dosing twice of eplerenone,





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spironolactone, amiloride lowers Systolic BP by 2.3 mm Hg on average. When spironolactone at 25 mg is poorly tolerated, eplerenone 100 mg or amiloride 10 mg can be used to reach nearly comparable potency. spironolactone and amiloride raise serum K^+ by 0.14-0.29mEq/l at widely used lower doses. Spironolactone, a mineralocorticoid receptor inhibitor, has been used for a long time. Spironolactone had almost faded from view (with the exception of its usage as a therapy for primary aldosteronism) till it get reintroduced for its use in the congestive heart failure. Spironolactone, in conjugation with a thiazide-type diuretic, can be quite beneficial in many patients with resistant hypertension and can also correct hypokalemia, as evidenced by the remarks connected to our case study. However, due of the antiandrogen activity of spironolactone, for men who use it, gynecomastia is a limiting side effect. Because premenopausal women who take spironolactone may experience menstrual abnormalities, spironolactone is more likely to be accepted by postmenopausal women.

In comparison to spironolactone, as a selective mineralocorticoid antagonist, eplerenone was newly developed with a much more acceptable adverse effect profile for a broader spectrum of patients.²³Eplerenone should be considered as an option for those who respond well to spironolactone but experience unacceptable side effects. Amiloride and triamterene are two commonly used medications that block the collecting duct's epithelial sodium transport channel. The hormone aldosterone controls the channel's entire activity. ENaC inhibitors reduce elimination potassium by preventing resorption of sodium through the epithelial sodium transport channel. When administered alone, epithelial Na^+ transport channel inhibitors have a limited influence on blood pressure and are best recognised for their K^+ saving abilities. In a large randomised outcome trial, an initial therapy, the pairing of a thiazide-like diuretics and amiloride (Coamilofid) was evaluated to the longer acting CCB nifedipine GITS. There was no relevant difference between the two therapies, according to the findings of this study. The diuretic combination did, however, show a non-significant tendency.²⁴In the United States, it's likely that the combining of a thiazide-like diuretic with a potassium-sparing medication like amiloride (less costly and generic pharmaceutical) is less used. hypertensives that are Salt-sensitive with increase mutations in the ENaC gene may develop an autosomal recessive condition (Liddle's syndrome), hinting that amiloride can help. In several larger population groups, heterozygotic patterns have been proposed as a possible explanation for salt-sensitive and amiloride-responsive hypertension.²⁴A schematic representation of potassium-sparing diuretics is shown in **Figure 7**.

SPIRONOLACTONE

Recently, the clinical aspects of SPIR have been outlined.²⁵SPIR has two antihypertensive mechanisms of action: Sodium-potassium exchange is inhibited at the mineral corticoid receptor in the kidney near the distal convoluted tubule and collecting duct junction., and (ii) antagonising aldosterone-induced vasoconstriction at receptors in the arterioles. In people with end-stage renal disease, a 6-8 mm Hg drop in diastolic and mean pressure (but not SBP) caused by SPIR helps the latter process.²⁶While the systolic effectiveness of SPIR has been reported to be larger than 20 mm Hg, the placebo-adjusted impact is more likely to be around 9 mm Hg.²⁷Although SPIR is commonly given twice daily, once daily dose has resulted in SBP decreases as significant as or greater than daytime.²⁸Spironolactone has been proven to decrease sudden death and total mortality in advanced heart failure patients, despite the fact that it has never been thoroughly evaluated for its efficiency in lowering CVEs in not selected hypertensives.²⁹Moreover, a recent study in hemodialysis patients found that Spironolactone at 25 mg reduced the basic result of cardiovascular death and hospital stays for CVEs by 60% (95 percent CI: 19% -80%), $P = 0.017$, with very few coronary and cerebrovascular incidents in the Spironolactone-treated group, despite having no effect on blood pressure.³⁰This experiment had a minimal risk of severe hyperkalemia, according to a meta-analysis of hemodialysis patients.³¹SPIR's order to decrease levels of protein in the urine by 61 percent in proteinuric renal disease, to reduce albuminuria by 60 percent in type 1 diabetic patients, to normalise left ventricular hypertrophy in main aldosteronism and low renin high blood pressure and to inhibit CTDN-induced sympathetic stimulation and insulin sensitivity in hypertensive patients suggests that it has non-ssn blood pressure-related benefits.³²⁻³⁵





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EPLERENONE

In comparison to other antihypertensives, EPLER induced a 1.5 mm Hg higher decrease in systolic BP but equivalent incidence of hyperkalemia in a current meta-analysis.³⁶ As previously stated, the dose equivalency of EPLER and SPIR is roughly 100 mg Eplerenone to 25 mg Spironolactone.³⁷ The activity of hormones and medicines on the collecting tubule is depicted in this simplified diagram in **Figure 8**.

INDAPAMIDE

INDAP, like CTDN, is a thiazide-type diuretic that acts more proximally on the distal convoluted tubule than hydrochlorothiazide. INDAP decreases Systolic BP by acting as a calcium antagonist such as vasorelaxant with a systolic effectiveness of 5 mm Hg higher than hydrochlorothiazide.^{38,39} Following a stroke in the elderly, and the usefulness of combining Indapamide with perindopril for preventing CVS disease in diabetics has been established.⁴⁰⁻⁴² INDAP outperformed hydrochlorothiazide in decreasing diabetic microalbuminuria, lowering left ventricular mass index, preventing platelet aggregation and lowering oxidative stress.⁴³ Furthermore, INDAP outperforms enalapril in terms of reducing left ventricular hypertrophy. INDAP, unlike other thiazides like CTDN, seems to have negligible action on metabolism of glucose or lipid. INDAP is sold in bargain pharmacies in the United States for \$4 per month. INDAP may be the finest thiazide/thiazide-like diuretic available, according to a recent analysis.

CLORTHALIDONE

CTDN is incorporated into RBC, resulting in a reserve with a Two-to-three-day activity period. In network analysis, CTDN proved more successful than HCTZ at reducing CVEs. In the ALLHAT research, CTDN was proven to be more efficient than lisinopril at minimizing CVEs and amlodipine at preventing congestive heart failure. While there have been concerns about CTDN's tolerability, the ALLHAT study found that after 5 years, control of blood pressure in the amlodipine, clortalidone, and lisinopril groups was 68, 66, and 61 percent, respectively. Furthermore, safety concerns about hypokalemia and hyperglycemia at CTDN dosages of 12.5-25 mg appear to be unfounded.⁴⁴

CONCLUSION

Diuretics are a prominent, wide range of antihypertensives that have been used in clinical practice for decades. However, their antihypertensive and therapeutic effects can be hindered in a variety of situations, such as when nonsteroidal anti-inflammatory medications are used at the same time, as mentioned above. Dietary factors can also play a significant role. Excess salt intake prevents diuretics' antihypertensive impact, possibly by counteracting depletion of volume and cardiac output, an "acute" stage that may be essential for the long run, diuretic treatment causes a "chronic" vasodilatory condition. chlortalidone and hydrochlorothiazide-amiloride, indapamide, triamterene-hydrochlorothiazide, and SPIR have all been shown to minimize CVEs in large-scale clinical trials involving CHF and end-stage kidney disease. Choosing the proper prescription and dose optimizes diuretic delivery in a number of conditions, including as hypertension that are salt-sensitive, and that is common in the overweight, the geriatric, and black people. In the situation of low renin hypertension, diuretics stimulate renin in an amount of the drug way, which would boost the effectiveness of ACE inhibitors and aldosterone receptor blockers. About 5 percent of all adults have resistive hypertension, which is a growing cause of illness and mortality. In the treatment of resistant hypertension, diuretics are crucial. Potassium-saving diuretics are almost certainly underused. The proportion of salt-sensitive individuals (i.e., the overweight and geriatric) is growing, and the SPRINT study suggests that many of them should keep their systolic blood pressure below 120mm/Hg.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

REFERENCES

1. Alderman MH, Piller LB, Ford CE, Probstfield JL, Oparil S, Cushman WC, et al. Clinical significance of incident hypokalemia and hyperkalemia in treated hypertensive patients in the antihypertensive and lipid-lowering treatment to prevent heart attack trial. *Hypertension*. 2012;59(5):926–33.
2. Baker EH, Duggal A, Dong Y, Ireson NJ, Wood M, Markandu ND, et al. Amiloride, a specific drug for hypertension in black people with T594M variant? *Hypertension*. 2002;40(1):13–7.
3. Baker WL, White WB. Safety of Mineralocorticoid Receptor Antagonists in Patients Receiving Hemodialysis. *Annals of Pharmacotherapy*. 2012;46(6):889–94.
4. Barzilay JI, Davis BR, Pressel SL, Cutler JA, Einhorn PT, Black HR, et al. Long-term effects of incident diabetes mellitus on cardiovascular outcomes in people treated for hypertension the ALLHAT diabetes extension study. *Circ Cardiovasc Qual Outcomes*. 2012;5(2):153–62.
5. O'Rourke MF, Namasivayam M, Adji A. Treatment of hypertension in patients 80 years of age or older. *Minerva Med*. 2009;100(1):25–38.
6. Brown MJ, Palmer CR, Castaigne A, De Leeuw PW, Mancia G, Rosenthal T, et al. Morbidity and mortality in patients randomised to double-blind treatment with a long-acting calcium-channel blocker or diuretic in the International Nifedipine GITS study: Intervention as a Goal in Hypertension Treatment (INSIGHT). *Lancet*. 2000;356(9227):366–72.
7. Chalmers J, Arima H, Woodward M, Mancia G, Poulter N, Hirakawa Y, et al. Erratum: Effects of combination of perindopril, indapamide, and calcium channel blockers in patients with type 2 diabetes mellitus: results from the action in diabetes and vascular disease: preterax and diamicon controlled evaluation (ADVANCE) trial (*Hyp*). *Hypertension*. 2015;66(1):e2.
8. Dahal K, Kunwar S, Rijal J, Alqatahni F, Panta R, Ishak N, et al. The effects of aldosterone antagonists in patients with resistant hypertension: A meta-analysis of randomized and nonrandomized studies. *Am J Hypertens*. 2015;28(11):1376–85.
9. Fujimura N, Noma K, Hata T, Soga J, Hidaka T, Idei N, et al. Mineralocorticoid receptor blocker eplerenone improves endothelial function and inhibits Rho-associated kinase activity in patients with hypertension. *Clin Pharmacol Ther*. 2012;91(2):289–97.
10. Garg R, Rao AD, Baimas-George M, Hurwitz S, Foster C, Shah R V., et al. Mineralocorticoid receptor blockade improves coronary microvascular function in individuals with type 2 diabetes. *Diabetes*. 2015;64(1):236–42.
11. Hall JJ, Eurich DT, Nagy D, Tjosvold L, Gamble JM. Thiazide Diuretic-Induced Change in Fasting Plasma Glucose: a Meta-analysis of Randomized Clinical Trials. *J Gen Intern Med*. 2020;35(6):1849–60.
12. Hermida RC, Ayala DE, Mojón A, Chayán L, Domínguez MJ, Fontao MJ, et al. Comparison of the effects on ambulatory blood pressure of awakening versus bedtime administration of torasemide in essential hypertension. *Chronobiol Int*. 2008;25(6):950–70.
13. Kaplan NM. Indapamide: Is it the better diuretic for hypertension? *Hypertension*. 2015;65(5):983–4.
14. Davis HE. Association between chlorthalidone treatment of systolic hypertension and long-term survival. *Cardiology Review*. 2012;28(2).
15. Kostis JB, Wilson AC, Freudenberger RS, Cosgrove NM, Pressel SL, Davis BR. Long-term effect of diuretic-based therapy on fatal outcomes in subjects with isolated systolic hypertension with and without diabetes. *American Journal of Cardiology*. 2005;95(1):29–35.
16. Kostis, W. J., Cabrera, J., Messerli, F. H., Cheng, J. Q., Sedjro, J. E., Cosgrove, N. M. et al. (2014). Competing cardiovascular and noncardiovascular risks and longevity in the systolic hypertension in the elderly program.
17. Krakoff LR. Diuretics for hypertension. *Circulation*. 2005;112(10).



**Rashmi Pathak et al.,**

18. Siragy HM. Major outcomes in high-risk hypertensive patients randomized to angiotensin-converting enzyme inhibitors or calcium channel blocker vs diuretic. The Antihypertensive and Lipid-Lowering Treatment to Prevent Heart Attack Trial (ALLHAT). *Curr Hypertens Rep.* 2003;5(4):293–4.
19. Matsumoto Y, Mori Y, Kageyama S, Arihara K, Sugiyama T, Ohmura H, et al. Spironolactone reduces cardiovascular and cerebrovascular morbidity and mortality in hemodialysis patients. *J Am Coll Cardiol.* 2014;63(6):528–36.
20. Morales E, Millet VG, Rojas-Rivera J, Huerta A, Gutiérrez E, Gutiérrez-Solís E, et al. Renoprotective effects of mineralocorticoid receptor blockers in patients with proteinuric kidney diseases. *Nephrology Dialysis Transplantation.* 2013;28(2):405–12.
21. Musini VM, Rezapour P, Wright JM, Bassett K, Jauca CD. Blood pressure-lowering efficacy of loop diuretics for primary hypertension. *Cochrane Database of Systematic Reviews.* 2015;2015(5).
22. Neaton JD, Kuller LH. Diuretics are color blind. *JAMA.* 2005;293(13):1663–6.
23. Nielsen SE, Persson F, Frandsen E, Sugaya T, Hess G, Zdunek D, et al. Spironolactone diminishes urinary albumin excretion in patients with type 1 diabetes and microalbuminuria: A randomized placebo-controlled crossover study. *Diabetic Medicine.* 2012;29(8).
24. Engberink RHGO, Frenkel WJ, Van Den Bogaard B, Brewster LM, Vogt L, Van Den Born BJH. Effects of thiazide-type and thiazide-like diuretics on cardiovascular events and mortality: Systematic review and meta-analysis. *Hypertension.* 2015;65(5):1033–40.
25. Oxlund CS, Buhl KB, Jacobsen IA, Hansen MR, Gram J, Henriksen JE, et al. Amiloride lowers blood pressure and attenuates urine plasminogen activation in patients with treatment-resistant hypertension. *Journal of the American Society of Hypertension.* 2014;8(12):872–81.
26. Pelliccia F, Patti G, Rosano G, Greco C, Gaudio C. Efficacy and safety of eplerenone in the management of mild to moderate arterial hypertension: Systematic review and meta-analysis. *Int J Cardiol.* 2014;177(1):219–28.
27. Pitt, B., Zannad, F., Remme, W. J., Cody, R., Castaigne, A., Perez, A. et al. (1999). The effect of spironolactone on morbidity and mortality in patients with severe heart failure. Randomized Aldactone Evaluation Study Investigators.
28. Psaty, B. M., Lumley, T., & Furberg CD (2004). Meta-analysis of health outcomes of chlorthalidone-based vs nonchlorthalidone-based low-dose diuretic therapies.
29. Psaty, B. M., Lumley, T., Furberg, C. D., Schellenbaum, G., Pahor, M., Alderman, M. H. et al. (2003). Health outcomes associated with various antihypertensive therapies used as first-line agents: a network meta-analysis.
30. MacMahon S, Neal B, Tzourio C, Rodgers A, Woodward M, Cutler J, et al. Randomised trial of a perindopril-based blood-pressure-lowering regimen among 6105 individuals with previous stroke or transient ischaemic attack. *Lancet.* 2001;358(9287):1033–41.
31. Roush GC, Ernst ME, Kostis JB, Kaur R, Sica DA. Not Just Chlorthalidone: Evidence-Based, Single Tablet, Diuretic Alternatives to Hydrochlorothiazide for Hypertension. *Curr Hypertens Rep.* 2015;17(4).
32. Roush GC, Ernst ME, Kostis JB, Tandon S, Sica DA. Head-to-head comparisons of hydrochlorothiazide with indapamide and chlorthalidone: Antihypertensive and metabolic effects. *Hypertension.* 2015;65(5):1041–6.
33. Roush GC, Ernst ME, Kostis JB, Yeasmin S, Sica DA. Dose doubling, relative potency, and dose equivalence of potassium-sparing diuretics affecting blood pressure and serum potassium: Systematic review and meta-analyses. *J Hypertens.* 2016;34(1):11–9.
34. Saseen JJ, Ghushchyan V, Nair K V. Comparing Clinical Effectiveness and Drug Toxicity With Hydrochlorothiazide and Chlorthalidone Using Two Potency Ratios in a Managed Care Population. *J Clin Hypertens.* 2015;17(2):134–40.
35. Schohn DC, Jahn HA, Pelletier BC. Dose-related cardiovascular effects of spironolactone. *Am J Cardiol.* 1993;71(3).
36. Sica DA. Mineralocorticoid Receptor Antagonists for Treatment of Hypertension and Heart Failure. *Methodist Debakey Cardiovasc J.* 2015;11(4):235–9.



**Rashmi Pathak et al.,**

37. Srivastava, S. K., & Srivastava R. Text book Pharmacology for Pharmacy Students, : Avichal Publishing Company.
38. Tripathi KD. A Text book Essential of Medical Pharmacology (8 ed.): Jaypee Brothers Medical Publishers.
39. Vaclavik J, Sedlak R, Plachy M, Navratil K, Plasek J, Husar R, et al. Addition of spironolactone in patients with resistant arterial hypertension (ASPIRANT) - study protocol. Biomedical Papers. 2011;155(2):143–8.
40. Van Blijderveen JC, Straus SM, Rodenburg EM, Zietse R, Stricker BH, Sturkenboom MC, et al. Risk of hyponatremia with diuretics: Chlorthalidone versus hydrochlorothiazide. American Journal of Medicine. 2014;127(8):763–71.
41. Waeber B, Rotaru C, Feihl F. Position of indapamide, a diuretic with vasorelaxant activities, in antihypertensive therapy. Expert Opin Pharmacother. 2012;13(10):1515–26.
42. Weinberger MH, Roniker B, Krause SL, Weiss RJ. Eplerenone, a Selective Aldosterone Blocker, in mild-to-moderate hypertension. Am J Hypertens. 2002;15(8):709–16.
43. Wright JT, Dunn JK, Cutler JA, Davis BR, Cushman WC, Ford CE, et al. Outcomes in hypertensive black and nonblack patients treated with chlorthalidone, amlodipine, and lisinopril. JAMA. 2005;293(13):1595–608.
44. Arjun HR, Halagali P, Tausi YM, Paramakrishnan N, Rakshith UR. Role of Stem Cells in the Management of Type-I Diabetes Mellitus. Indian Journal of Pharmaceutical Education and Research. 2023;57(4):951–5.
45. Das S, Mukherjee T, Mohanty S, Nayak N, Mal P, Ashique S, et al. Impact of NF-κB Signaling and Sirtuin-1 Protein for Targeted Inflammatory Intervention. Curr Pharm Biotechnol [Internet]. 2024 Apr 17;25.
46. Sharma H, Kaushik M, Goswami P, Sreevani S, Chakraborty A, Ashique S, et al. Role of miRNAs in Brain Development. MicroRNA. 2024 Apr 2;13.
47. Ashique S, Bhowmick M, Pal R, Khatoun H, Kumar P, Sharma H, Garg A, Kumar S, Das U. Multi drug resistance in colorectal cancer-approaches to overcome, advancements and future success. Advances in Cancer Biology-Metastasis. 2024 Jan 12:100114.
48. Ashique S, Pal R, Sharma H, Mishra N, Garg A. Unraveling the Emerging Niche Role of Extracellular Vesicles (EVs) in Traumatic Brain Injury (TBI). CNS & Neurological Disorders Drug Targets. 2024 Feb 13.
49. Kumar P, Pandey S, Ahmad F, Verma A, Sharma H, Ashique S, et al. Carbon Nanotubes: A Targeted Drug Delivery against Cancer Cell. Curr Nanosci. 2023 Nov 8;9:1–31.
50. Sharma H, Chandra P, Verma A, Pandey SN, Kumar P, Singh A. Therapeutic approaches of nutraceuticals in the prevention of neurological disorders. Eur Chem Bull. 2023;12(5):1575 – 1596.
51. Sharma H, Chandra P. Challenges and Future Prospects: A Benefaction of Phytoconstituents on Molecular Targets Pertaining to Alzheimer's Disease. Int J Pharm Investig. 2023 Dec 27;14(1):117–26.
52. Sharma H, Pathak R, Jain S, Bhandari M, Mishra R, Reena K, Varshney P. Ficus racemosa L: A review on its important medicinal uses, phytochemicals and biological activities. Journal of Population Therapeutics and Clinical Pharmacology. 2023 Jul 15;30(17):213-27.
53. Singh LP, Gugulothu S, Perusomula R, Mishra A, Bhavani PD, Singh S, Sharma H, Dwivedi M. Synthesis of Some Tetrazole and Thiazolidine-4-One Derivatives of Schiff base by using Ionic Liquids as Catalyst and Evaluation of their Antifungal and Antibacterial Activity. Eur. Chem. Bull. 2023, 12 (Special Issue8),281-297.
54. Pathak, Rashmi & Sharma, Himanshu & Nogai, Lipi & Bhandari, Maulshree & Koli, Manju & Mishra, Riya & Kumar, N. A Brief Review on Pathogenesis, Transmission and Management of Monkeypox Virus Outbreaks. Bull. Environ. Pharmacol. Life Sci. 2023, 12 (4), 244–256.
55. Sharma H, Bhattacharya V, Bhatt A, Garg S, Chaurasia G, Akram W, Sharma K, Mandal S. "Optimization of formulation by box Behnken and in-vitro studies of emulsified gel containing zaltoprofen for the management of arthritis" in Eur. Chem. Bull. 2023,12(Special Issue 4),11734-11744.
56. Koli M, Nogai L, Bhandari M, Mishra R, Pathak R, Sharma H. Formulation And Evaluation Of Berberine Hydrochloride Film Coated Tablet. Journal of Pharmaceutical Negative Results. 2023 Feb 10:3439-49.
57. Dwivedi M, Jha KK, Pandey S, Sachan A, Sharma H, Dwivedi SK. Formulation and Evaluation of Herbal Medicated Chocolate in Treatment of Intestinal Worms and Related Problems. IJFANS. 2022, 11 (2), 1426-1439.





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58. Sharma H, Pathak R, Kumar N, Nogai L, Mishra R, Bhandari M, Koli M, Pandey P. Endocannabinoid System: Role in Depression, Recompense, And Pain Control. *Journal of Survey in Fisheries Sciences*. 2023 Apr 17;10(4S):2743-51.
59. Sharma H, Pathak R, Saxena D, Kumar N. "Emerging role of non-coding RNA'S: human health and diseases" in GIS. 2022, 9 (7) 2022-2050.
60. Sharma H, Rani T, Khan S. An Insight into Neuropathic Pain: A Systemic and up-to-Date Review. *IJPSR* 2023, 14(2):607–621.
61. Pandey P, Kumar N, Kaur T, Saini S, Sharma H. Antidiabetic Activity of *Caesalpinia Bonducella* Leaves of Hydro Alcoholic Extracts in Albino Rats. *YMER*. 2022, 7(21), 840-846.
62. Pathak R, Sharma H, Kumar N. A Brief Review on *Anthocephalus cadamba*. *Acta Scientific Pharmacology*. 2022 May;3(5).
63. Sharma S, Dinda SC, Sharma H, Matrix types drug delivery system for sustained release: a review, *ASIO Journal of Drug Delivery (ASIO-JDD)*, 2022, 6(1): 01-08.
64. Sharma H, Pathak R. A REVIEW ON PRELIMINARY PHYTOCHEMICAL SCREENING OF *CURCUMA LONGA LINN*. *J Pharma Herbal Med Res (ASIO-JPHMR)*. 2021;7(2):24-27.
65. Pathak R, Sharma H. A review on medicinal uses of *Cinnamomum verum* (Cinnamon). *Journal of Drug Delivery and Therapeutics*. 2021 Dec 15;11(6-5):161-6.
66. Sharma H, Pande M, Jha KK, Hyperuricemia: a risk factor beyond gout, *ASIO Journal of Pharmaceutical & Herbal Medicines Research (ASIO-JPHMR)*, 2020, 6(1), 42-49.
67. Sharma H, Singh S, Jha KK, Treatment and recommendations for homeless patients with hypertension, hyperlipidemia & heart failure-a review, *ASIO Journal of Experimental Pharmacology & Clinical Research (ASIO-JEPCR)*, 2020, 6(1): 24-32.
68. Sharma H, Rachamalla HK, Mishra N, Chandra P, Pathak R, Ashique S. Introduction to Exosome and Its Role in Brain Disorders BT - Exosomes Based Drug Delivery Strategies for Brain Disorders. In: Mishra N, Ashique S, Garg A, Chithravel V, Anand K, editors. Singapore: Springer Nature Singapore; 2024. p. 1–35.
69. Sharma H, Tyagi SJ, Chandra P, Verma A, Kumar P, Ashique S, et al. Role of Exosomes in Parkinson's and Alzheimer's Diseases BT - Exosomes Based Drug Delivery Strategies for Brain Disorders. In: Mishra N, Ashique S, Garg A, Chithravel V, Anand K, editors. Singapore: Springer Nature Singapore; 2024. p. 147–82.
70. Kumar P, Sharma H, Singh A, Pandey SN, Chandra P. Correlation Between Exosomes and Neuro-inflammation in Various Brain Disorders BT - Exosomes Based Drug Delivery Strategies for Brain Disorders. In: Mishra N, Ashique S, Garg A, Chithravel V, Anand K, editors. Singapore: Springer Nature Singapore; 2024. p. 273–302.
71. Sharma H, Chandra P. Effects of natural remedies on memory loss and Alzheimer's disease. *Afr.J.Bio.Sc.* 6(7) (2024).187-211.
72. Hwang AY, Dietrich E, Pepine CJ, Smith SM. Resistant hypertension: mechanisms and treatment. *Current Hypertension Reports*. 2017 Jul;19:1-1.

Table1. Diuretics' action site and mechanism

	Diuretics	The location of the action	Mechanism of action
1.	CAI (acetazolamide)	PCT	Inhibition of CA
2.	Loop diuretics (frusemide)	ThAL (loop of Henle)	Co-transport of sodium, potassium, and chloride (Na/K/2Cl) is inhibited.
3.	Thiazides (hydrochlorothiazide)	DCT	Inhibition of Na/Cl co-transport
4.	K ⁺ sparing diuretic		





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	(a)Aldosterone antagonist (spironolactone)	Collecting tubule (cortex)	Blocks MR
	(b)Triamterene & amiloride (cortex)	Collecting tubule	Blocks epithelial Na ⁺ channel
5.	Osmotic diuretics (mannitol)	Des. LOH, PCT	Osmotic action (increase osmolality)
6.	ADH antagonists (conivaptan)	Collecting tubule	Blocks vasopressin receptors

Table 2: Diuretics indications, contraindications, and side effects

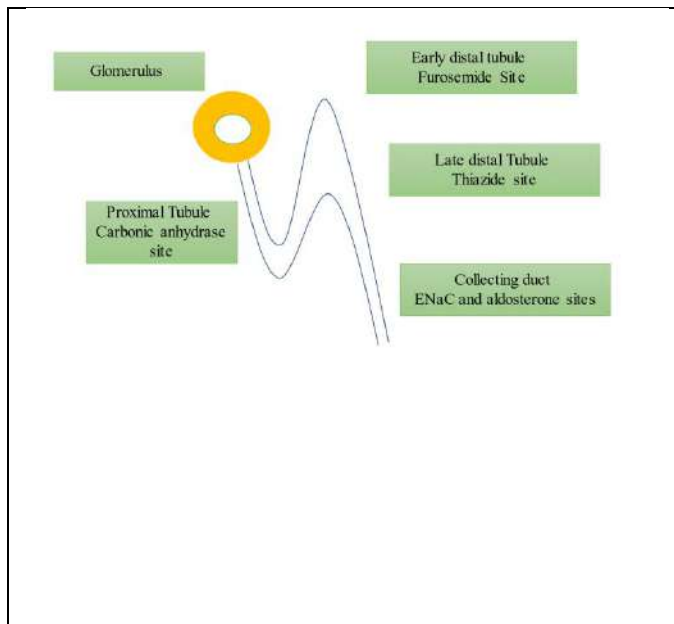
Subclass	Indications	Contraindications	Adverse effects	Reference
Thiazides	Calcium stones in the kidneys, nephrogenic diabetes insipidus, and moderate edoema.	Gout and sensitivity to sulfa compounds	Na ⁺ , K ⁺ , and Mg ⁺ are the electrolytes that cause orthostatic hypotension. Alkalosis metabolic. Calcium, uric acid, glucose, cholesterol, and triglycerides levels in the bloodstream are all higher. Lithium poisoning and erectile dysfunction	45-50
Agents that act like thiazides (e.g., chlorthalidone and indapamide)	There are two types of hypertension: higher blood pressure and sensitive hypertension.	Ditto	Ditto	51-55





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<p>Amiloride and Triamterene are potassium-saving pteridines.</p>	<p>Hypertension caused by a lack of potassium and/or magnesium, Liddle's syndrome, and pteridine derivatives</p>	<p>Hyperkalemia ($K > 5$ mmol/l), concurrent use of ACEIs or ARBs (relative), early renal failure, and pregnancy are all risk factors (particularly triamterene)</p>	<p>Increased K^+, Cl^-, and H^+ levels in the blood. Amiloride or triamterene may induce vomiting, bloating, and a rash on the skin; triamterene can also cause nephrolithiasis. In men, spironolactone induces gynecomastia and a reduction in libido.</p>	<p>56-60</p>
<p>Aldosterone antagonists include pironolactone and eplerenone.</p>	<p>High blood pressure caused by a lack of potassium and/or magnesium, resistant hypertension, primary aldosteronism, and other mineralocorticoid disordersexcess, CHF are all treated with aldosterone antagonists.</p>			<p>61-72</p>



Graphical Abstract

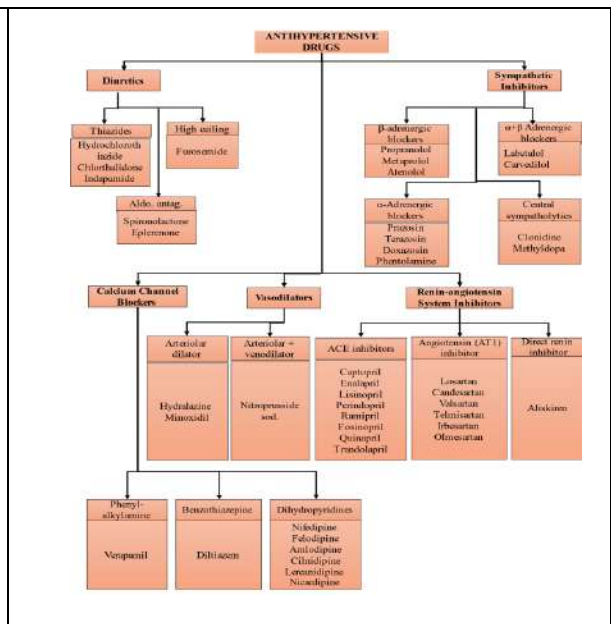


Figure 1:Classification of Antihypertensive Drugs





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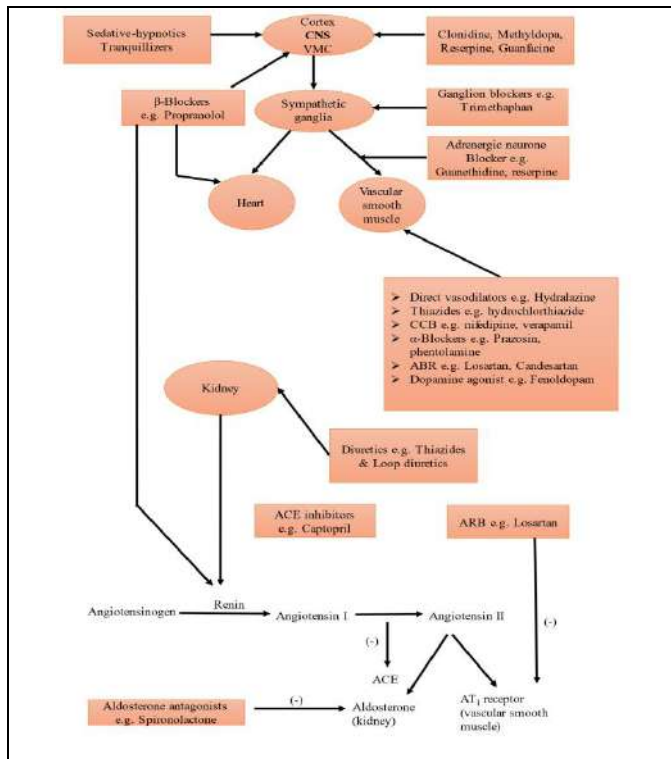


Figure 2: Schematic representation of the site of action of various antihypertensive drugs. VMC- vasomotor center; ARB- angiotensin receptor blocker; CCB- calcium channel blocker; ACE- angiotensin-converting enzyme AT, Angiotensin receptor

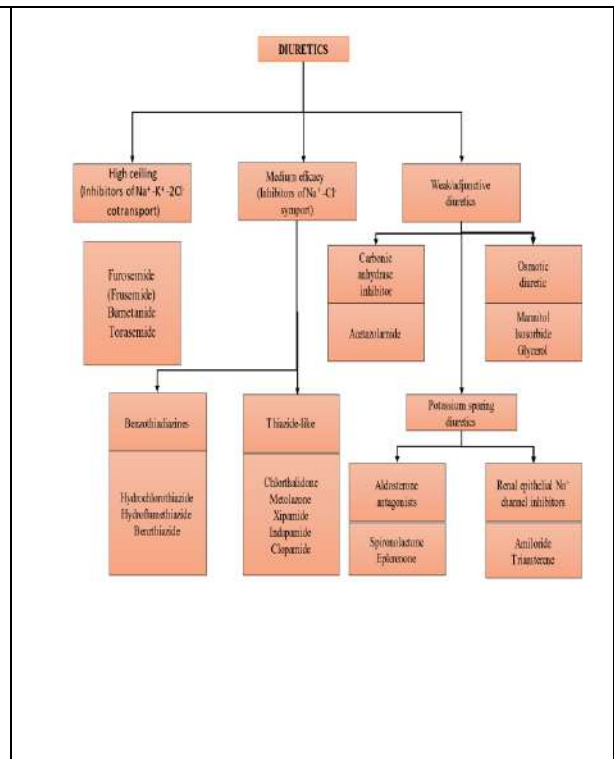


Figure 3: Classification of Diuretics

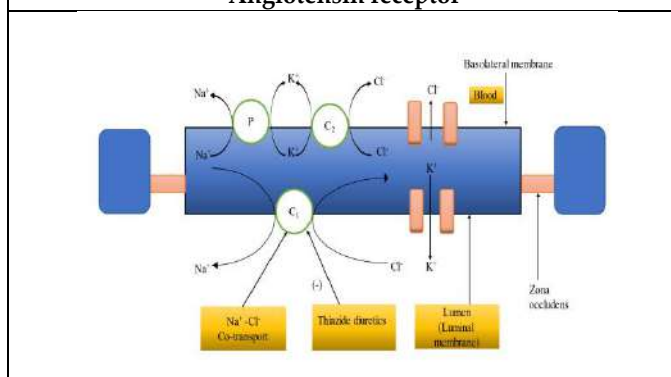


Figure 4: Transport through the distal convoluted tubule and the location of action of thiazide diuretics are depicted in a simplified schematic. Sodium pump (Na+ K+ ATPase); Na+ - Cl- enters the cell by Co-transport (C1); some potassium is carried out via Co-transport and returns to the lumen via potassium channel.

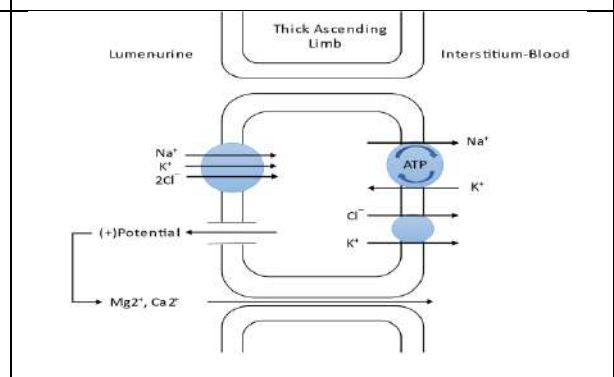


Figure 5: Loop-Active Diuretics





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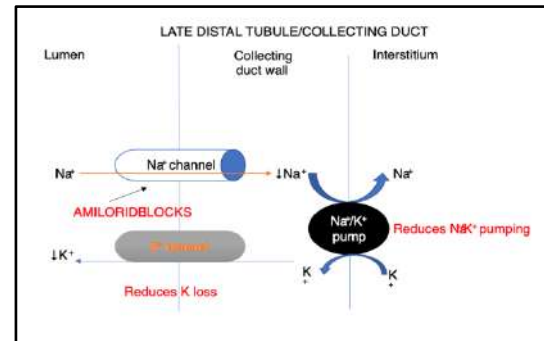
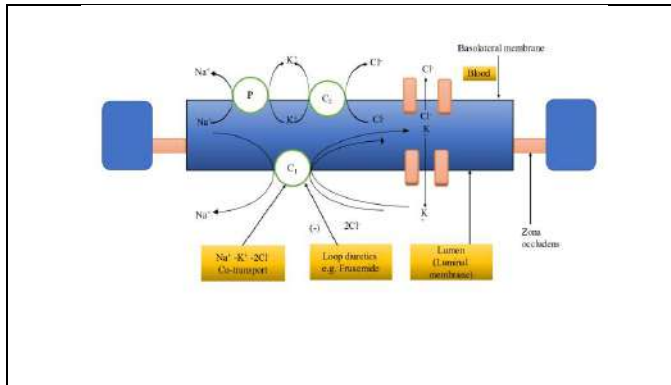


Figure 6: Ion transport in the thick ascending loop of the Henle and the location of action of loop diuretics are depicted in a simplified schematic. P-Sodium ($\text{Na}^+ - \text{K}^+ - 2\text{Cl}^-$) enters the cell by co-transport (C_1), while chloride exits via chloride channel and $\text{K}^+ - \text{Cl}^-$ Co-transport (C_2)

Figure 7:Potassium-sparing diuretics

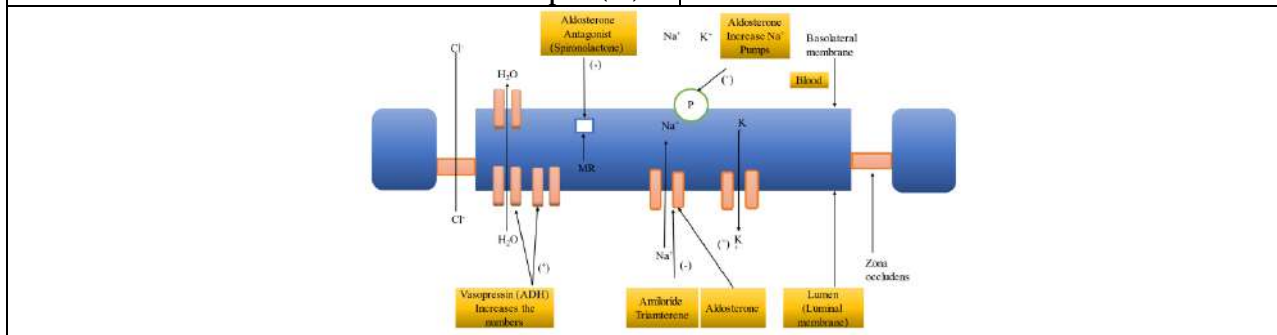


Figure 8: The activity of hormones and medicines on the collecting tubule is depicted in this simplified diagram. P stands for sodium pump ($\text{Na}^+ \text{K}^+ \text{ATPase}$); MR is mineralocorticoid receptor; and ADH stands for antidiuretic hormone. In the absence of ADH, the cells in the collecting tubule are not permeable to water, and they are not permeable to sodium in the lack of aldosterone. Aldosterone binds to both cell surface and nuclear receptors to create the impact. Chloride ions depart the tubule via the paracellular route, and the filtrate is supplemented with K^+ and H^+ ions. Spironolactone inhibits the MR receptor, while amiloride and triamterene inhibit epithelial sodium channels, resulting in a diuretic effect





Comparative Study on Types of MPPT Algorithms used in Photovoltaic Systems

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ABSTRACT

As the global pursuit of sustainable power generation expands, the demand for renewable energy sources is increasing significantly. To meet this growing demand, the development of the renewable energy sector is of great importance. Solar energy has emerged as one of the pivotal players in this progress. However, certain factors, such as the efficiency and reliability of the solar energy conversion system, are crucial to their widespread adoption. The inherent fluctuations in sunlight lead to voltage variations that affect the stability of the power converters used and, hence, there liability of the system itself. Various controllers based on Maximum Power Point Tracking(MPPT) are employed to address this issue. This paper focuses on the design and implementation of advanced controllers to effectively regulate voltage variations in the energy conversion process. Three MPPT algorithms, namely, Perturb and Observe algorithm, Incremental Conductance method, and Fuzzy Logic Controllers, have been analysed and compared based on their effectiveness in different environmental conditions.

Keywords: Renewable energy, solar energy conversion, voltage variations, controllers, MPPT algorithm, P&O, incremental conductance, fuzzy logic.





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INTRODUCTION

The transition to renewable energy, particularly solar, addresses climate change and reduces fossil fuel dependence. However, solar insolation varies daily and seasonally, posing challenges for extensive use. Designing efficient power conversion systems is essential to manage voltage variations, inconsistent power supply, and inefficiency in energy harvesting. Since the DC output of Photovoltaic (PV) systems is insufficient for large loads, converters transform solar power for DC loads or the grid. Controllers are crucial for managing voltage variations in solar energy systems. The controller employs Maximum Power Point Tracking (MPPT) to optimize energy extraction from solar panels under changing environmental conditions [1]. In [2] various DC-DC converters such as boost converter, bi-directional DC-DC converter, LLC converter and novel topologies of the converter are designed and tested to have high efficiency.[3] discusses combining the MPPT controller with the PI controller to regulate voltage and output power under fluctuating irradiance and temperature conditions. The PI controller is advantageous as it reduces steady-state error and increases system stability.[4] review the known MPPT algorithms and classify them based on the number of control variables used, types of control strategies, circuitry, and cost involved, which are essential for selecting an MPPT technique for a particular application and the converter preferred for each MPPT technique. In [5] Perturb and Observe (P&O) technique of MPPT algorithm is tested under varying external conditions and its drawbacks are overcome by developing an improved P&O model. [6] presents the incremental conductance (IC) algorithm of MPPT. The efficiency obtained in IC method surpasses that of P&O method. Improved IC methods incorporating fuzzy logic are also proposed which further improve the efficiency and reliability of the system. In [7], the design and modelling of a fuzzy logic controller (FLC) for tracking the Maximum Power Point (MPP) of a PV system is presented. The use of artificial neural networks enhances the FLC algorithm, making it superior for PV systems. In this paper, a sophisticated controller capable of regulating voltage fluctuations in solar power converters is developed. The controller is designed to accommodate various MPPT algorithms such as Perturb and Observe (P&O), Incremental Conductance method (IC) and Fuzzy Logic Control (FLC). The solar power conversion system with the integrated controller is modelled using MATLAB. The performance of each algorithm is evaluated by analysing key parameters such as response time, accuracy, harmonics and efficiency under varying solar irradiance. The block diagram of the proposed system is shown in Fig.1.

MATERIALS AND METHODS

PHOTOVOLTAIC SYSTEM

Fundamentals of PV System

A Photovoltaic (PV) system converts sunlight into electricity using silicon-based PV cells through the photovoltaic effect. Key components include the PV array, DC-DC converter, battery storage, controllers, inverter, and load (or grid). PV panels can be connected in series to sum output voltages while keeping the current constant, or in parallel to sum output currents while maintaining the same voltage. The output of a PV array depends on factors. Higher irradiance increases power production, while higher temperatures above 25°C decrease it. Optimal tilt and orientation maximize sunlight exposure. Obstructions like trees or buildings, partial shading of panels, and dust accumulation significantly reduce efficiency. Converters are essential to address these limitations and maintain PV system reliability.

DC-DC Converters

The converters are set up with energy storage elements namely capacitors, inductors, switching elements and diodes in various designs capable of either stepping up or stepping down (or both) the input voltage. Its main function is to ensure that the output of the PV panel matches with that of the load. Some of the DC-DC converters commonly used with MPPT algorithms for maximum efficiency are non-isolated converters such as buck converter, boost converter, buck-boost converter, CUK converter, SEPIC converter, LUO, Zeta converter and isolated fly back converters [8]. In this paper, boost converter was chosen as the appropriate DC-DC converter owing to its continuous input-output





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energy flow, low input current ripple, simplicity in design and its property to produce non-inverted output. The schematic diagram of boost converter is shown in Fig. II.

STUDY ON CONTROLLERS

To get a constant output voltage at various conditions, a closed loop control system is implemented in the circuit. Therefore, adjusting the load characteristics so that the system output has maximum power in real time, i.e., to achieve the maximum power point tracking (MPPT), is very important in PV systems. The output of the PV array is given as input to the control unit which modifies the duty cycle required for PWM generation. The duty ratio is then compared with the carrier signal and given to the transistor (in the converter) as control signal. Three MPPT controllers are implemented in this paper- Perturb and Observe, Fuzzy Logic Controller and Incremental Conductance Controller.

Perturb and Observe (P&O)

A small perturbation or disturbance is given to cause a variation of power in the PV module [9]. The output PV power is calculated by taking the product of the voltage and the current value. This power is then compared with zero based on the difference between present and previous values. If there is an increase in output power, then perturbation is continued to be given in the same direction. Otherwise, the perturbation is given by reversing it. There are two sub-cases:

1. The operating point is to the left of MPP when an increase in voltage leads to the power difference being positive. Then, perturbation is given towards the right to reach the required MPP or the duty ratio of the converter is reduced.
2. The operating point is to the right of MPP when a voltage increases leads to a negative change in power. Then, perturbation is given to the left to attain MPP, or the duty ratio of the converter is increased. The flowchart describing the P&O algorithm is shown in Fig.III.

Fuzzy Logic Controller (FLC)

A fuzzy logic controller (FLC) consists of three main blocks: fuzzification, inference engine, and defuzzification. The FLC takes in two inputs given by Eq.1 and Eq.2 and produces one output.

$$E = \frac{P(n) - P(n-1)}{V(n) - V(n-1)} \quad (1)$$

$$\Delta E = E(n) - E(n-1) \quad (2)$$

where, n and n-1 represent the present and previous state respectively. The error indicates the slope of the P-V curve, thereby giving information on the location of MPP. The movement of the operating point toward or away from the MPP is defined by the change in error. The fuzzification block assigns these input signals corresponding fuzzy values based on the membership function. The triangular membership function is defined for this control. The fuzzified data is then interpreted by the inference engine based on predefined rules. The Mamdani approach was used to obtain the inference. The defuzzification block utilizes the same membership function as the fuzzification block to produce a crisp value from the fuzzy output of the inference engine. The output obtained from the defuzzification block is the change in duty ratio, which is applied to the DC-DC converter [10]. The flowchart of the FLC algorithm is given in Fig.IV.

Incremental Conductance (IC)

The IC algorithm ascertains the slope of the Power vs Voltage(P-V) curve, and the maximum power point is obtained by finding the peak of the P-V curve [11]. When the IC algorithm concludes by reaching the Maximum Power Point, it settles and stops moving around the operating point. The Maximum Power Point is obtained by comparing the instantaneous conductance(I/V), to the incremental conductance(dI/dV). Based on the relationship between the two values, the location of the operating point of the PV module in the P-V curve can be determined. Being able to determine when the MPP has been reached is possible because the slope is negative when the MPPT is to the right of





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the MPP ($V > V_{mp}$) as given by Eq.3 and positive when it is to the left of the MPP($V < V_{mp}$), given by Eq.4 and when the slope is zero, given by Eq.5, the MPP is established ($V = V_{mp}$).

$$\frac{dI}{dV} > -\frac{I}{V} \quad (3)$$

$$\frac{dI}{dV} < -\frac{I}{V} \quad (4)$$

$$\frac{dI}{dV} = -\frac{I}{V} \quad (5)$$

Eq. 5 can be written as,

$$I + V \frac{dI}{dV} = 0 \quad (6)$$

In the IC method, Eq. 6, is used to detect the maximum power point, and the current and voltage of the PV module are measured by the MPPT controller. If Eq. 3 is satisfied, the duty cycle of the converter has to be decreased, and the duty cycle of the converter has to be increased, if Eq. 4 is satisfied, whereas the duty cycle remains same if Eq. 5 is satisfied.

RESULTS

To study and evaluate the performance of the proposed MPPT schemes, a simulation study is carried out by using MATLAB Simulink tool. A load which is affected by the variation in voltages is chosen. RL loads used in appliances such as washing machines are chosen as the load for simulating this model. A 120V, 1200W load with resistance 5Ω was chosen for this paper. The parameters of the boost converter are designed assuming that the current ripple is 30% of the load current and the voltage ripple is 1% of the output voltage. The design parameters for the boost converter is given by Table I. The boost converter, for the given load, was modelled as shown in Fig. V. The output voltage waveform of the above boost converter is shown in Fig. VI

Perturb and Observe (P&O) Method

The MATLAB model for the designed PV system utilizing P&O method of MPPT algorithm is shown in Fig.VII.

The output voltage waveform of the system is obtained as viewed in Fig. VIII. It is seen that this method shows large oscillations or deviations around MPP. And it exhibits a trade-off between tracking accuracy and tracking speed. The settling time is observed to be very high.

Fuzzy Logic Method

The controller was designed with MATLAB Fuzzy Logic Toolbox. The Mamdani controller model with defuzzification method was used and this procedure was carried out using the fuzzy inference system editor (FIS editor). The model is shown in Fig. IX. The output voltage waveform of the designed model is obtained as shown in Fig. X. It is observed that the FLC algorithm produces an output with fast convergence with small oscillations.

Incremental Conductance (IC) Method

The MATLAB model for designed PV system using Incremental conductance algorithm is shown in Fig. XI. The output waveform of voltage is obtained as seen in Fig. XII. From these waveforms, it is noted that there are deviations at various intervals which can be attributed to the variations in irradiance. The settling time for this technique is around 0.02 sec. Also, in the beginning, it is observed that there is a delay which is caused by transients. The results also show that the voltage output is affected by the sudden change in irradiation and thereby, it is consequential that the power output of the boost converter is also affected by it.





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DISCUSSIONS

After analysis, it is inferred that while Perturb and Observe (P&O) is simple to implement, it suffers from oscillations around the Maximum Power Point (MPP) and has a larger response time. The Incremental Conductance (IC) method performs better under rapidly changing irradiance conditions and has a faster response time than P&O, but it is more complex and requires more components. Fuzzy Logic Control (FLC) offers robust performance under varying conditions and uncertainties but is infrequently used due to its highly complex design and the need for tuning PI controllers and fuzzy logic rules. In terms of efficiency, IC outperforms P&O and FLC. P&O is the simplest to implement, while FLC is the most complex but highly adaptive and robust under dynamic conditions. IC has the fastest response time among the three methods. Table II provides a brief comparison of these methods. Careful analysis shows that designing controllers for power converters with Maximum Power Point Tracking (MPPT) algorithms is essential for managing voltage variations in solar energy conversion, ensuring efficiency under varying conditions. Incremental Conductance and Perturb and Observe methods are popular due to their simplicity and good performance. These controllers have a profound societal impact by promoting renewable energy adoption and mitigating climate change. Ongoing research in advanced MPPT techniques enhances sustainable energy solutions, significantly contributing to the global shift towards renewable sources.

REFERENCES

1. Gouda, E. A., Kotb, M. F., &Elalfy, D. A. (2019). Modelling and performance analysis for a PV system based MPPT using advanced techniques. *European Journal of Electrical Engineering and Computer Science*, 3(1).
2. Meshael, H., Elkhateb, A., & Best, R. (2023). High Gain Isolated Switched-Boost DC-DC Converter for PV Application. In *2023 IEEE International Conference on Environment and Electrical Engineering and 2023 IEEE Industrial and Commercial Power Systems Europe (EEEIC/I&CPS Europe)* (pp. 1-6). IEEE.
3. Swain, Nibedita. (2016). Application of PI and MPPT Controller to DC-DC Converter for Constant Voltage & Power Application. *IOSR Journal of Electrical and Electronics Engineering*. 11. 08-15. 10.9790/1676-1105030815.
4. Subudhi, B., & Pradhan, R. (2012). A comparative study on maximum power point tracking techniques for photovoltaic power systems. *IEEE transactions on Sustainable Energy*, 4(1), 89-98.
5. Ali, A. I. M., & Mohamed, H. R. A. (2022). Improved P&O MPPT algorithm with efficient open-circuit voltage estimation for two-stage grid-integrated PV system under realistic solar radiation. *International Journal of Electrical Power & Energy Systems*, 137, 107805.
6. Asoh, D. A., Noumsi, B. D., & Mbinkar, E. N. (2022). Maximum Power Point Tracking Using the Incremental Conductance Algorithm for PV Systems Operating in Rapidly Changing Environmental Conditions. *Smart Grid and Renewable Energy*, 13(5), 89-108.
7. Narendiran, S., Sahoo, S. K., Das, R., & Sahoo, A. K. (2016). Fuzzy logic controller based maximum power point tracking for PV system. In *2016 3rd International Conference on Electrical Energy Systems (ICEES)* (pp. 29-34). IEEE.
8. Harsha, S., Naveen, B., Murali, J., Vamsi, C., Karam, M., & Mishra, S. (2021). Analysis of DC-DC Converters for Renewable Energy System. In *2021 4th International Conference on Recent Developments in Control, Automation & Power Engineering (RDCAPE)* (pp. 11-15). IEEE.
9. Zhan, J., Zhou, Y., Zhu, X., & Lin, H. (2023, November). Research on maximum power point tracking of PV systems based on perturbation and observation method. In *International Conference on Electronic Materials and Information Engineering (EMIE 2023)* (Vol. 12919, pp. 182-188). SPIE.
10. Rezk, H., Aly, M., Al-Dhaifallah, M., & Shoyama, M. (2019). Design and hardware implementation of new adaptive fuzzy logic-based MPPT control method for photovoltaic applications. *Ieee Access*, 7, 106427-106438.
11. Shang, L., Guo, H., & Zhu, W. (2020). An improved MPPT control strategy based on incremental conductance algorithm. *Protection and Control of Modern Power Systems*, 5, 1-8.





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Table 1: Boost converter specifications

PARAMETER	VALUE
Duty ratio	50%
Input Voltage	60V
Output Voltage	120V
Capacitance value	0.00083F
Inductance value	0.001H

Table 2: Comparison of MPPT algorithms

PARAMETER	P&O	IC	FLC
Efficiency (%)	95-98	97-99	96-99
Response time(sec)	0.1	0.01	0.05
Complexity	Low	Moderate	High
Suitability for shading	Not suitable	Suitable under certain situation	Good adaptability to partial shading
Robustness	Less	Moderate	High

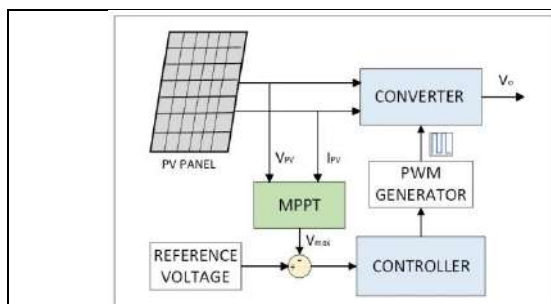


Fig I: Block Diagram of the Proposed System

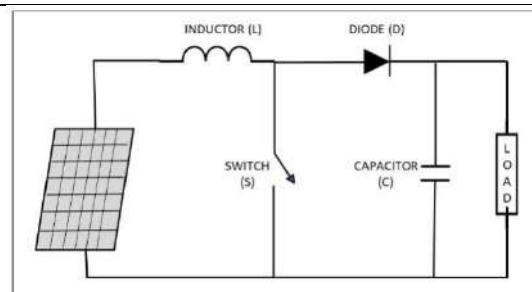


Fig II: Schematic diagram of boost converter





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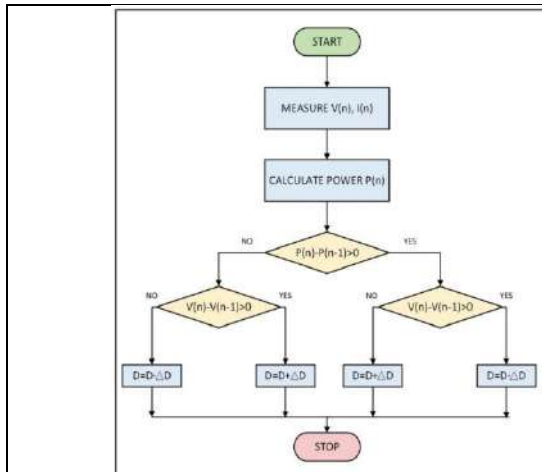


Fig III: P&O algorithm flowchart

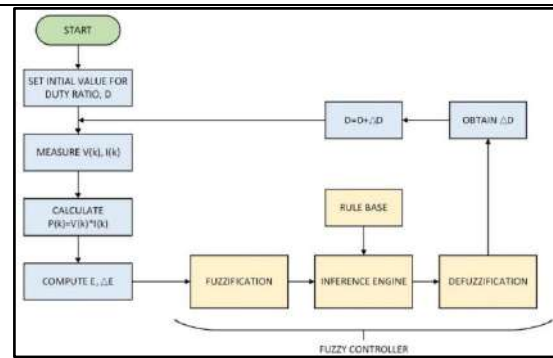


Fig IV: FLC algorithm flowchart

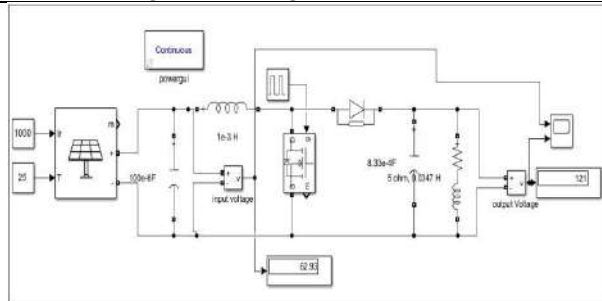


Fig V: Boost converter model

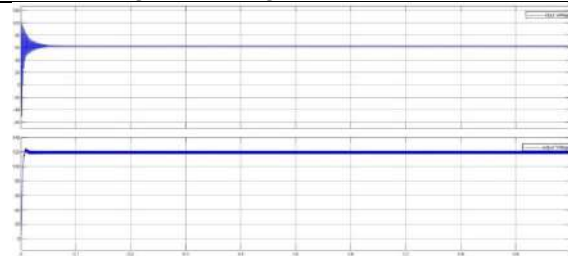


Fig VI: Output Waveform of Boost Converter

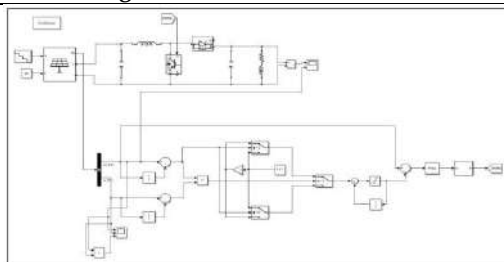


Fig VII: P&O MATLAB Model

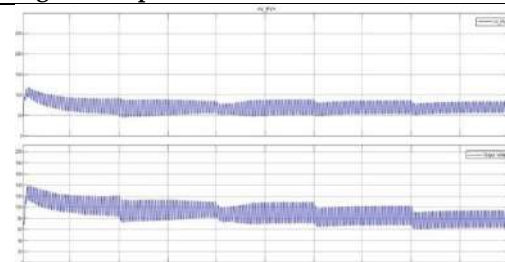


Fig VIII: P&O output waveform

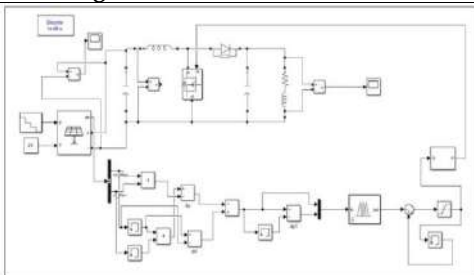


Fig IX: FLC MATLAB Model

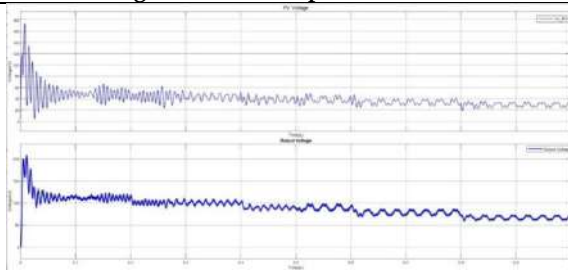


Fig X: FLC output waveform





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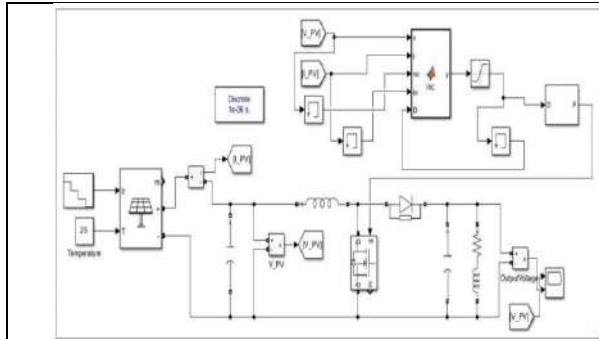


Fig XI: IC MATLAB Model

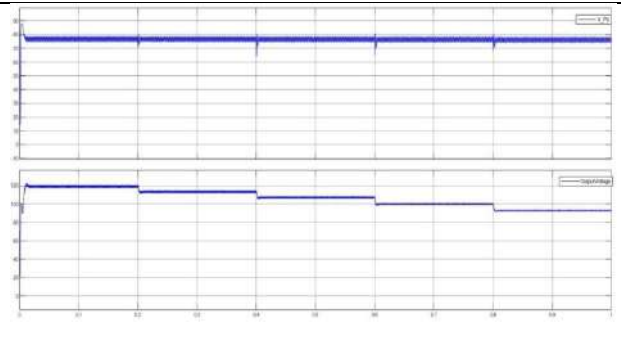


Fig XII: IC Output Waveform





Anti-inflammatory and Comparative Antioxidant Activity of *Datura metel* L. Leaf Aqueous and Alcoholic Extract

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ABSTRACT

Datura metel L. is a widely used medicinal plant in traditional Ayurveda medicine. It has a variety of therapeutic uses like anti-inflammatory, anti-arthritic, anaesthetic, hallucinogenic, anti-asthmatic, bronchodilator, antispasmodic, narcotic, and anti-tussive. Among these activities, anti-inflammatory has a significant therapeutic role. *Datura* has been used as an external application for inflammation since ancient times. The presence of withanolides, tannins and ketones exhibits the anti-inflammatory activity of the plant. Antioxidants help to avoid inflammatory reactions, demonstrating their anti-inflammatory potential. The current work aims to study the anti-inflammatory activity and compare the antioxidant potential of *Daturametel* leaf aqueous and alcoholic extracts.

Keywords: *Daturametel* L., Anti-oxidant activity, Anti-inflammatory activity, Phytochemical, Traditional medicine.





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INTRODUCTION

Datura (Datura metel L.) is a widely-known medicinal plant belonging to the Solanaceae family.[1]*Datura* is a perennial herbaceous plant that grows in both temperate and tropical climates. In Traditional medicine, *Datura* has been used to treat a variety of conditions, including pain, fever, and dyspnoea. It has potent deliriant and hallucinogenic properties. Higher doses of the alkaloids, which are responsible for both therapeutic and hallucinogenic effects, are hazardous, and reckless usage frequently results in hospitalization and fatalities. Based on these observations, the plant has been classified under Schedule E-1 of the Drug and Cosmetics Act of 1940. Although it is a poisonous plant, it has been utilized by Ayurvedic physicians for a variety of purposes since ancient times. According to Ayurveda classics, all parts of the plants are used as medicinal drugs either alone or in combination with other drugs for various diseases. In clinical practices, most Physicians and Traditional healers use *Datura metel* leaf for anti-inflammatory activity externally in a paste form.[2]The antioxidant activity of *Datura metel* may protect tissues from damage and prevent unwanted inflammatory responses occurring in the body. Although *Datura metel* is having antioxidant potential, the current study is aimed to compare the antioxidant activity of aqueous and alcohol extracts of the drug.

MATERIALS AND METHODS

Collection and authentication of the drug

The plant material used in the present study was collected from Shahapur, Belagavi district, Karnataka and authenticated by the AYUSH-certified Central Research Facility of Shri BMK Ayurveda Mahavidyalaya. The freshly collected plant material was dried under shade and the dried material was milled to obtain a fine powder.

Extraction of aqueous and alcoholic extract of *Datura metel* leaves

The aqueous extraction of *Datura metel* L. leaves was done with the cold maceration extraction method in the AYUSH certified Central research facility of Shri BMK Ayurveda Mahavidyalaya. Accurately weighed 10gm of *Datura* leaf powder is macerated with 100 ml distilled water for 48 hours at room temperature in a flask shaker. For alcoholic extract, instead of water 100 ml of ethanol was used. The marc is extracted by several times using the same procedure. The extracts thus obtained were combined and filtered through Whatman No. 1 filter paper. The extracts are then concentrated with vacuum evaporation in a rotary evaporator and dried in a water bath to obtain the final crude extract.

Anti-oxidant activity of aqueous and alcoholic extract of *Datura metel* leaves

DPPH Assay was used to assess the anti-oxidant activity of *Datura metel* aqueous extract and alcohol extract. 0.066mM of the solution was prepared by weighing 2.6mg of DPPH (1,1 Diphenyl-2-picryl hydrazyl) in a 100ml volumetric flask sonicate and making up the volume to the mark with methanol. The sample was prepared in methanol. 1.5ml DPPH reagent was taken along with 1.5ml methanol taken as Blank. The samples were prepared in three concentrations i.e. 0.5ml, 1ml and 1.25ml. The reaction mixture was incubated at 37°C for 30 minutes. Absorbance is measured using a spectrophotometer at 516 nm. A graph is plotted on DPPH activity on the Y axis and concentration on the X axis and half maximal inhibitory concentration (IC50) value is calculated.

$$\text{DPPH Activity} = \frac{\text{Absorbance of Blank} - \text{Absorbance of sample}}{\text{Absorbance of Blank}} \times 100$$

Phytochemicals in *Datura Metel*

Search engines like Pubmed, Elsevier, Google Scholar, Microsoft academic research, Cochrane Library, Ayush Portal and Shodhganga had been searched for data collection about the phytochemicals in *Datura metel*. The structures of phytochemicals are collected from PubChem database. The anti-inflammatory activity of the phytochemicals was also identified.





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RESULTS

Antioxidant activity of *Datura metel* aqueous and alcohol extract by DPPH assay

The antioxidant activity of *Datura metel* aqueous and alcohol extract was examined by DPPH Assay. Table 1 and 2 shows the values of absorbance of the blank and absorbance of the sample for calculating the antioxidant activity of *Datura metel* leaf alcohol extract and aqueous extract respectively. Graph 1 and 2 demonstrate the DPPH activity of *Datura metel* alcohol extract and aqueous extract on the Y axis and concentrations on the X axis respectively. Table 3 shows the comparison of IC₅₀ values of aqueous and alcoholic extracts of *Datura metel* leaves.

Phytochemicals present in *Datura metel* leaves

A total of 22 out of 34 identified phytochemicals present in *Datura metel* possessed anti-inflammatory activity. [Table 4]

DISCUSSION

Datura is an Ayurveda classical drug used in a variety of inflammatory conditions either alone or in combination with other drugs. *Datura metel* leaves extracts possess antioxidant potential which helps to protect tissues from damage and prevent unwanted inflammatory responses. If the equilibrium of free radical and antioxidant defence mechanisms is disturbed, it can lead to oxidative stress and associated damage. This oxidative stress condition can cause injury to all vital cellular components and it may cause numerous diseases which include inflammation, diabetes, cardiovascular diseases, cancer, degenerative diseases, ischemia, and anemia. Among 34 phytochemicals identified from the leaves of *Datura metel*, 22 are showing anti-inflammatory activity. The IC₅₀ value is a parameter widely used to measure the antioxidant activity of the drug. It is calculated as the concentration of antioxidants needed to decrease the initial DPPH concentration by 50%. Thus, the lower the IC₅₀ value the higher the antioxidant activity. The results showed that the IC₅₀ value of the alcohol extract is less than the aqueous extract of *Datura metel* leaves. It was reported that the antioxidant activity of the *Datura metel* leaves extracts might be due to the presence of phenolic and flavonoid compounds. The study shows that the alcohol extract of *Datura metel* may have more anti-inflammatory activity than the aqueous extract of *Datura metel* in terms of antioxidant activity.

CONCLUSION

Datura is an extensively used medicinal plant used to treat a variety of diseases. The presence of chemical constituents like Scopolamine, atropine etc. makes the *Datura metel* L.a potent plant. The drug's seeds and leaves can be utilised as anti-inflammatory medications. The anti-inflammatory properties of the *Datura metel* are provided by the presence of withanolides, tannins, etc. The higher antioxidant activity of *Datura metel* leaves alcohol extract may show higher anti-inflammatory activity. So, *Daturametel* leaves alcohol extract might be utilized for the preparation of novel dosage forms.

REFERENCES

1. Sharma M, Dhaliwal I, Rana K, Delta AK, Kaushik P. Phytochemistry, Pharmacology, and Toxicology of *Datura* Species-A Review. *Antioxidants* (Basel). 2021 Aug 15;10(8):1291
2. Prof. P.V Sharma, Dravyagunavijnana, 2005, Chaukhambha Bharati academy, Varanasi,
3. National Center for Biotechnology Information. PubChem Compound Summary for CID 11392488, Daturabietatriene. <https://pubchem.ncbi.nlm.nih.gov/compound/Daturabietatriene>.
4. National Center for Biotechnology Information. PubChem Compound Summary for CID 222284, beta-Sitosterol. <https://pubchem.ncbi.nlm.nih.gov/compound/beta-Sitosterol>.





Sreeja Kaimal et al.,

5. Liao P-C, Lai M-H, Hsu K-P, Kuo Y-H, Chen J, Tsai M-C, et al. Identification of β -Sitosterol as in Vitro Anti-Inflammatory Constituent in *Moringa oleifera*. J Agric Food Chem [Internet]. 2018; 66(41):10748–59. Available from: <https://pubmed.ncbi.nlm.nih.gov/30280897/>
6. Baig MW, Nasir B, Waseem D, Majid M, Khan MZI, Haq I-U. Withametelin: a biologically active withanolide in cancer, inflammation, pain and depression. Saudi Pharm J [Internet]. 2020; 28(12):1526–37. Available from: <https://www.sciencedirect.com/science/article/pii/S1319016420302358>
7. National Center for Biotechnology Information. PubChem Compound Summary for CID 122724, Celastrol. <https://pubchem.ncbi.nlm.nih.gov/compound/Celastrol>.
8. Li T, Gao S, Han W, Gao Z, Wei Y, Wu G, et al. Potential effects and mechanisms of Chinese herbal medicine in the treatment of psoriasis. J Ethnopharmacol [Internet]. 2022;294(115275):115275. Available from: <https://pubmed.ncbi.nlm.nih.gov/35487447/>
9. Baig MW, Fatima H, Akhtar N, Hussain H, Okla MK, Al-Hashimi A, et al. Anti-inflammatory potential of daturaolone from *Datura innoxia* Mill.: In silico, in vitro and in vivo studies. Pharmaceuticals (Basel) [Internet]. 2021;14(12):1248. Available from: <https://pubmed.ncbi.nlm.nih.gov/34959649/>.
10. Bawazeer S, Rauf A, Bawazeer S. Gastrointestinal motility, muscle relaxation, antipyretic and acute toxicity screening of amyryn type triterpenoid (daturaolone) isolated from *Datura metel* Linnaeus (Angel's trumpet) fruits. Front Pharmacol [Internet]. 2020;11:544794. Available from: <http://dx.doi.org/10.3389/fphar.2020.544794>.
11. Pei Y-H, Kwon O-K, Lee J-S, Cha H-J, Ahn K-S, Oh S-R, et al. Triterpenes with cytotoxicity from the leaves of *Vernicia fordii*. Chem Pharm Bull (Tokyo) [Internet]. 2013;61(6):674–7. Available from: <https://pubmed.ncbi.nlm.nih.gov/23727783/>
12. Rath SN, Jena L, Bhuyan R, Mahanandia NC, Patri M. In silico discovery and evaluation of phytochemicals binding mechanism against human catechol-O-methyltransferase as a putative bioenhancer of L-DOPA therapy in Parkinson disease. Genomics Inform [Internet]. 2021;19(1):e7. Available from: <https://pubmed.ncbi.nlm.nih.gov/33840171/>.
13. Baig MW, Nasir B, Waseem D, Majid M, Khan MZI, Haq I-U. Withametelin: a biologically active withanolide in cancer, inflammation, pain and depression. Saudi Pharm J [Internet]. 2020; 28(12):1526–37. Available from: <https://www.sciencedirect.com/science/article/pii/S1319016420302358>
14. Diomede F, Marconi GD, Guarnieri S, D'Attilio M, Cavalcanti MFXB, Mariggìo MA, et al. A novel role of ascorbic acid in anti-inflammatory pathway and ROS generation in HEMA treated dental pulp stem cells. Materials (Basel) [Internet]. 2019 [cited 2022 Oct 5];13(1):130. Available from: <http://dx.doi.org/10.3390/ma13010130>
15. National Center for Biotechnology Information. PubChem Compound Summary for CID 54670067, Ascorbic acid. <https://pubchem.ncbi.nlm.nih.gov/compound/Ascorbic-acid>.
16. White PT, Subramanian C, Motiwala HF, Cohen MS. Natural withanolides in the treatment of chronic diseases. Adv Exp Med Biol [Internet]. 2016 ;928:329–73. Available from: <https://pubmed.ncbi.nlm.nih.gov/27671823/>.
17. Lem FF, Yong YS, Goh S, Chin SN, Chee FT. Withanolides, the hidden gem in *Physalis minima*: A mini review on their anti-inflammatory, anti-neuroinflammatory and anti-cancer effects. Food Chem [Internet]. 2022 ; 377(132002):132002. Available from: <https://pubmed.ncbi.nlm.nih.gov/35033733/>.
18. Ishola AO, Imam A, Ajao MS. Datumetine exposure alters hippocampal neurotransmitters system in C57BL/6 mice. Drug Chem Toxicol [Internet]. 2022; 45(2):785–98. Available from: <https://pubmed.ncbi.nlm.nih.gov/32847421/>
19. Nile SH, Nile A, Gansukh E, Baskar V, Kai G. Subcritical water extraction of withanosides and withanolides from ashwagandha (*Withaniasomnifera* L) and their biological activities. Food Chem Toxicol [Internet]. 2019 ;132(110659):110659. Available from: <https://pubmed.ncbi.nlm.nih.gov/31276745/>
20. Dey P, Kundu A, Kumar A, Gupta M, Lee BM, Bhakta T, et al. Analysis of alkaloids (indole alkaloids, isoquinoline alkaloids, tropane alkaloids). In: Recent Advances in Natural Products Analysis. Elsevier; 2020. p. 505–67





Sreeja Kaimal et al.,

21. Khattak KF, Atta-ur-Rahman, Choudhary MI, Hemalal KD, Tillekeratne LM. New tropane alkaloids from *Erythroxylummoonii*. J Nat Prod [Internet]. 2002 ;65(6):929–31. Available from: <https://pubmed.ncbi.nlm.nih.gov/12088442/>
22. O’rourke FJ, Gershon S, Trautner EM, Shaw FH. The use of tigloidine in the symptomatic treatment of spastic paraplegia. Med J Aust [Internet]. 1960 ;47(1)(1):73–7. Available from: <https://ur.booksc.me/book/84561397/d8387b>
23. Rubio C, Strano-Rossi S, Taberero MJ, Anzillotti L, Chiarotti M, Bermejo AM. Hygrine and cuscohygrine as possible markers to distinguish coca chewing from cocaine abuse in workplace drug testing. Forensic Sci Int [Internet]. 2013;227(1–3):60–3. Available from: <https://pubmed.ncbi.nlm.nih.gov/23063180/>
24. Yi P, Zhang Z, Huang S, Huang J, Peng W, Yang J. Integrated meta-analysis, network pharmacology, and molecular docking to investigate the efficacy and potential pharmacological mechanism of Kai-Xin-San on Alzheimer’s disease. Pharm Biol [Internet]. 2020 ;58(1):932–43. Available from: <http://dx.doi.org/10.1080/13880209.2020.1817103>
25. National Center for Biotechnology Information. PubChem Bioassay Record for AID 288766, Source: ChEMBL. <https://pubchem.ncbi.nlm.nih.gov/bioassay/288766>.
26. Kongkathip N, Dhumma-upakorn P, Kongkathip B, Chawanoraset K, Sangchomkao P, Hatthakitpanichakul S. Study on cardiac contractility of cycloeucalenol and cycloeucalenone isolated from *Tinosporacrispa*. J Ethnopharmacol [Internet]. 2002 ;83(1–2):95–9. Available from: <https://pubmed.ncbi.nlm.nih.gov/12413712/>
27. da Silva DM, Martins JLR, de Oliveira DR, Florentino IF, da Silva DPB, Dos Santos FCA, et al. Effect of allantoin on experimentally induced gastric ulcers: Pathways of gastroprotection. Eur J Pharmacol [Internet]. 2018;821:68–78. Available from: <https://www.sciencedirect.com/science/article/pii/S0014299917308531>
28. National Center for Biotechnology Information. PubChem Compound Summary for CID 204, Allantoin. <https://pubchem.ncbi.nlm.nih.gov/compound/Allantoin>.
29. Nazemi M, Ghafari H, Seddiq Mortazavi M, Ahmadiataba MA, Aghasadeghi MR. The cytotoxic activity of lanosterol isolated from sea cucumber *Holothurialeucospilota* from Hengam island, Persian Gulf. Aquatics Physiology and Biotechnology [Internet]. 2018 ;5(4):41–55. Available from: https://japb.guilan.ac.ir/article_2726.html?lang=en
30. Wang W, Yang Y-P, Tasneem S, Daniyal M, Zhang L, Jia Y-Z, et al. Lanostane tetracyclic triterpenoids as important sources for anti-inflammatory drug discovery. World J Tradit Chin Med [Internet]. 2020;6(3):229. Available from: <https://www.wjtcn.net/article.asp?issn=23118571;year=2020;volume=6;issue=3;spage=229;epage=238;aulast=Yan g>
31. Tanaka M, Misawa E, Yamauchi K, Abe F, Ishizaki C. Effects of plant sterols derived from *Aloe vera* gel on human dermal fibroblasts in vitro and on skin condition in Japanese women. Clin Cosmet Invest Dermatol [Internet]. 2015 ;8:95–104. Available from: <http://dx.doi.org/10.2147/CCID.S75441>
32. Chen J, Tang G, Zhou J, Liu W, Bi Y. The characterization of soybean germ oil and the antioxidative activity of its phytosterols. RSC Adv [Internet]. 2019 ;9(68):40109–17. Available from: <https://pubs.rsc.org/en/content/articlelanding/2019/ra/c9ra08771k>
33. Cardoso CR, Favoreto S Jr, Oliveira LL, Vancim JO, Barban GB, Ferraz DB, et al. Oleic acid modulation of the immune response in wound healing: a new approach for skin repair. Immunobiology [Internet]. 2011;216(3):409–15. Available from: <https://pubmed.ncbi.nlm.nih.gov/20655616/>
34. National Center for Biotechnology Information. PubChem Compound Summary for CID 445639, Oleic acid. <https://pubchem.ncbi.nlm.nih.gov/compound/Oleic-acid>.
35. Bassaganya-Riera J, Hontecillas R, Beitz DC. Colonic anti-inflammatory mechanisms of conjugated linoleic acid. Clin Nutr [Internet]. 2002;21(6):451–9. Available from: <https://www.sciencedirect.com/science/article/pii/S0261561402905947>
36. National Center for Biotechnology Information. PubChem Compound Summary for CID 5280450, Linoleic acid. <https://pubchem.ncbi.nlm.nih.gov/compound/Linoleic-acid>.





Sreeja Kaimal et al.,

37. Guo R, Liu Y, Xu Z-P, Xia Y-G, Yang B-Y, Kuang H-X. Withanolides from the leaves of *Datura metel* L. *Phytochemistry* [Internet]. 2018;155:136–46. Available from: <https://pubmed.ncbi.nlm.nih.gov/30121428/>
38. Yang B-Y, Guo R, Li T, Wu J-J, Zhang J, Liu Y, et al. New anti-inflammatory withanolides from the leaves of *Datura metel* L. *Steroids* [Internet]. 2014 ;87:26–34. Available from: <https://pubmed.ncbi.nlm.nih.gov/24844203/>
39. Yang B-Y, Guo R, Li T, Liu Y, Wang C-F, Shu Z-P, et al. Five withanolides from the leaves of *Datura metel* L. and their inhibitory effects on nitric oxide production. *Molecules* [Internet]. 2014, 19(4):4548–59. Available from: <https://www.mdpi.com/1420-3049/19/4/4548>
40. Ma L, Xie C-M, Li J, Lou F-C, Hu L-H. Daturametelins H, I, and J: three new withanolide glycosides from *Datura metel* L. *Chem Biodivers* [Internet]. 2006 ;3(2):180–6. Available from: <https://pubmed.ncbi.nlm.nih.gov/17193256/>

Table 1: Antioxidant Activity of *Datura Metel* Leaves Alcohol Extract

No. of sample	Ab.of Blank	Ab.of sample	Conc.in ppm	Antioxidant Activity
1	0.3291	0.3238	18.3	1.61045275
2	0.3291	0.2453	91.3	25.46338499
3	0.3291	0.1198	237.5	63.59769067

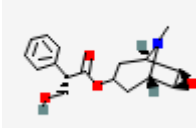
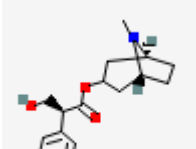
Table 2: Antioxidant Activity of *Datura metel* Aqueous Extract

No.of sample	Ab.ofBlank	Ab.Of sample	Conc.in ppm	AntioxidantActivity
1	0.3431	0.2719	118.4	20.75196736
2	0.3431	0.2058	197.3	40.01748761
3	0.3431	0.1257	315.7	63.36345089

Table 3: Comparison of IC50 (Half-Maximal Inhibitory Concentration) Value of Aqueous and Alcoholic Extract of *Datura metel* Leaves

	Aqueous extract	Alcohol extract
Antioxidant activity IC50 value of <i>Datura metel</i>	251.23 mg/Kg	186.85mg/Kg

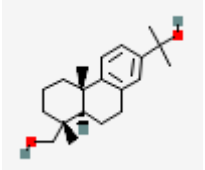
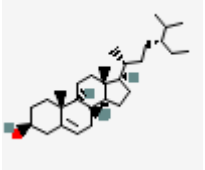
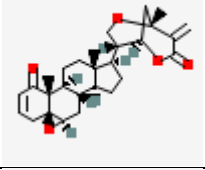
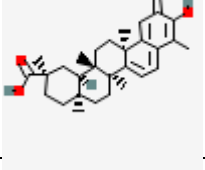
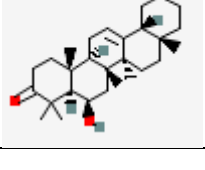
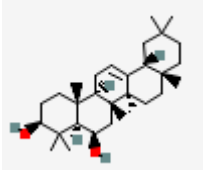
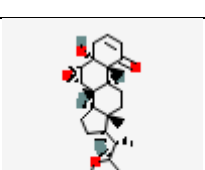
Table 4: Phytochemicals Present in *Datura metel* Along with Anti-Inflammatory Activity

Sl no	Phytochemicals	Parts	Activities of Phytochemicals	Anti-inflammatory activity	Structures
1.	Hyoscine ^[3,4]	Aerial part, flower. Fruit, leaf, Root	Anti-inflammatory, Useful in Nausea, Vomiting, Motion Sickness, Muscle Spasm	*	
2.	Hyoscyamine ^[5]	Aerial part, Bark, Flower, Leaf, Root	Anti-inflammatory, helpful for overactive bladder, mild to moderate motion sickness, and allergic rhinitis.	-	





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3.	Daturabietatriene ^[6]	Bark	Anti- inflammatory, anti-proliferative	*	
4.	beta-Sitosterol ^[7,8]	Bark, fruit 5	Anti-inflammatory Anti-cholesteremic drug, Antioxidant	*	
5.	Withametelin F ^[9]	Flower, Leaf	Anti-inflammatory	*	
6.	Celastrol ^[10,11]	fruit	Anti-inflammatory, antioxidant,	*	
7.	Daturaolone ^[12,13]	Fruit, Seed	Anti-inflammatory, gastrointestinal motility, muscle relaxation, and antipyretic activity	*	
8.	Daturadiol ^[14]	Fruit	Exhibit Moderate cytotoxicity against HepG2 (hepatocellular carcinoma), SK-OV-3 (ovarian carcinoma), A-549 (lung carcinoma) and SNU-1 (gastric carcinoma) human cancer cell lines.	-	
9.	Withanolide B ^[15]	Leaf	Potential bioenhancer in Parkinson's disease L-DOPA therapy	-	






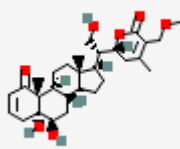

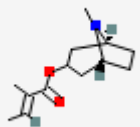

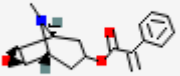
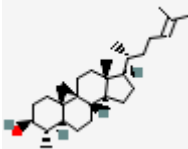
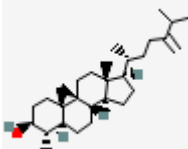
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10.	Withametelin ^[16]	Leaf	Useful in Inflammation, Cancer, Pain and Depression	*	
11.	Withametelin E ^[16]	Leaf	Useful in Inflammation, Cancer, Pain and Depression	*	
12.	Ascorbic acid ^[17-18]	Leaf	Anti-inflammatory, antioxidant, treatment for acidity of the urine, scurvy, delayed bone and wound healing, and vitamin C deficiency	*	
13.	Withanolide S ^[19-20]	Leaf	the ability to reduce inflammation, neuroinflammation, and malignancy.	*	
14.	Withametelin C ^[16]	Leaf	Useful in Inflammation, Cancer, Pain and Depression	*	
15.	Withametelin B ^[16]	Leaf	Useful in Inflammation, Cancer, Pain and Depression	*	
16.	Withametelin D ^[16]	Leaf	Useful in Inflammation, Cancer, Pain and Depression	*	
17.	Datumetine ^[21]	Leaf	alters hippocampal neurotransmitter systems	-	





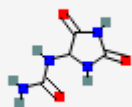
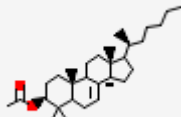
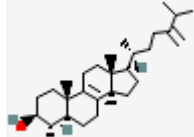
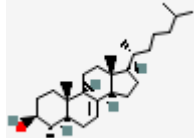
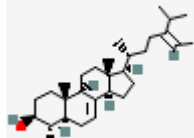
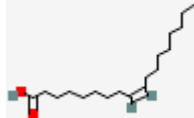
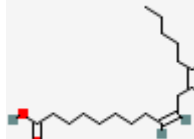
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18.	12-Deoxywithastramonolide ^[22]	Leaf	antioxidant, and enzyme inhibitory activities	-	
19.	Withametelin H ^[16]	Leaf	Useful in Inflammation, Cancer, Pain and Depression	*	
20.	Tropane ^[23,24]	Root, Seed	Anti-inflammatory, anaesthetic, anticholinergic, antiemetic, antihypertensive, parasympatholytic	*	
21.	Tropigline/ Tigloidine ^[25]	Root	Useful in spastic paraplegia	-	
22.	Cuscohygrine ^[26]	Root	possible markers to distinguish coca chewing	-	
23.	Aposcopolamine ^[27]	Root	Useful in Alzheimer's disease	-	
24.	31-Norcycloartenol ^[28]	Seed	Anti-tumour initiators	-	
25.	Cycloeucalenol ^[29]	Seed	alter cardiac contractility	*	





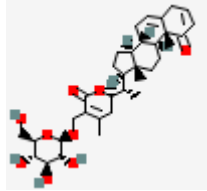
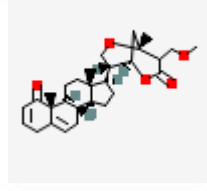
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26.	Allantoin ^[30,31]	Seed	hydrating skin, increasing skin smoothness, promoting wound healing, and soothing irritated skin	*	
27.	31-Nor-7-lanosterol acetate ^[32]	Seed	Cytotoxic activity	-	
28.	Obtusifoliol ^[33]	Seed	Anti-inflammatory	*	
29.	Lophenol ^[34]	Seed	stimulated collagen reduces facial wrinkles	-	
30.	alpha1-Sitosterol/ Citrostadienol ^[35]	Seed	Antioxidant activity	-	
31.	Oleic acid ^[36,37]	Seed	Anti-inflammatory, food additive	*	
32.	Linoleic acid ^[38, 39]	Seed	Anti-inflammatory, Preeclampsia	*	

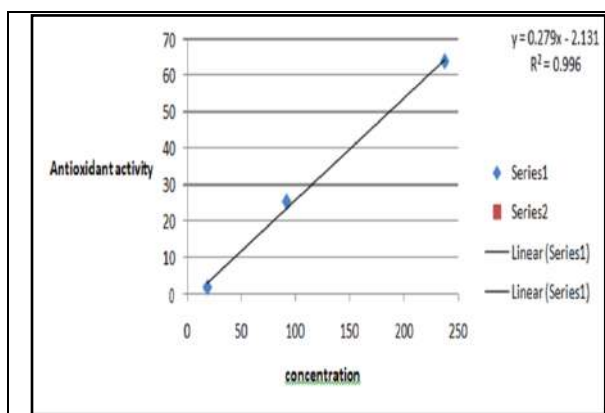




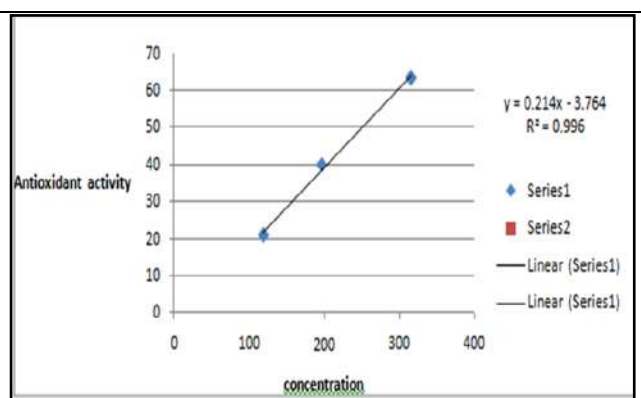
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33.	Daturametelin A ^[40]	Whole plant	Anti-inflammatory	*	
34.	Daturametelin D ^[40]	Aerial part	Anti-inflammatory	*	

*Mark Showing the anti-inflammatory activity



Graph 1:Antioxidant activity of *Datura metel* leaves alcohol extract by DPPH Assay



Graph 2: Antioxidant activity of *Datura metel* leaves aqueous extract by DPPH Assay





RESEARCH ARTICLE

A Brief Insight into Viability and *In vitro* Pollen Germination Behavior of Ridged Gourd from Malda District of West Bengal

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ABSTRACT

Pollens of *Luffa acutangula* L. showed great variation in respect to their viability and germination percentage. Viability showed increasing trend from first day of collection to eighth day of collection both in case of pollens collected in the morning as well as in the evening. The day wise viability percentages were higher in case of pollens collected in the evening than those collected in the morning. Sucrose and Boric acid solution individually showed positive correlation in respect to hour wise *in vitro* pollen germination where 500 ppm concentration were found to be most effective. In combination of 400 ppm sucrose with 50ppm boric acid were found to be most potent in exerting maximum germination efficacy.

Keywords: Sucrose, Boric acid, Pollen tube, *Luffa acutangula* L., germination, *in vitro*.





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INTRODUCTION

Pollen grains are anatomically simple organ compared to other highly differentiated tissues and other plant organ developing inside the anther locules bearing sporophytic gene products at maturity. Reaching a receptive stigma, a pollen grain transforms its stored RNA, protein, and bioactive small molecules allowing rapid germination of a pollen tube that penetrate through inside the style, where it deposit two male gametes. Inside the embryo sac, male gametes fuse with the egg and central cell to form the zygote and endosperm respectively. Assessment of pollen quality indicates plant fertility, ecological or investigations, pollen chemistry, pollen-pistil interactions, genetics and conservation ecology [1]. Viability refers to the ability of the pollen to deliver functional sperm cells to the embryo sac following compatible pollination. [Shivanna et al]. Pollen nourishment is an important factor for pollen viability [2]. The quality of pollen is assessed on the basis of viability and vigor. Investigation of pollen viability is a time consuming process and not always feasible. Therefore, many shortcut methods which would reflect the functional ability of the pollen have been devised. Light microscopy is one of the most important techniques for examining pollen quality since it allows clear observation of pollen morphology. Direct observation of pollen under microscope will confirm location of grains inside the anthers, and will also differentiate between undifferentiated or grossly shrunken grains and abortive or infertile grains. Other important techniques for assessing pollen quality are *in vitro* germination test and fluorescein diacetate (FDA). Retention time of pollen viability after shedding is highly variable [3]. Assessment of pollen viability includes investigation on bio chemical changes during pollen germination and growth of the pollen tube through the use of direct methods [4]. Due to their ability to attain considerable length within a short period of time under favourable conditions, the pollen tubes are considered as one of the most actively dividing plant cells. In recent years, study of pollen germination is an important paradigm of research to determine the importance of cytoskeleton in cell growth and differentiation.

Pollen grains are highly reduced male gametophytes consisting of 2-3 cells at the time of their discharge which are involved in transmitting the male genetic material during sexual reproduction of angiosperms [5]. Germination of pollen grain is regarded as the first critical morphogenetic towards its ultimate function of liberation of male nuclei in the vicinity of the egg. [6]. Elongation of the pollen tube is a lively process where the tip of the pollen tube penetrates the female tissue to accomplish their ultimate goal of delivering the sperm cells for fertilization. Pollen tube extends exclusively at the cell apex via an extreme form of polar growth, known as tip growth, producing uniformly set cylindrical cells. *Luffa acutangula* Roxb. is a common vine, belonging to the family Cucurbitaceae, known as "Ridged gourd" which is an annual herb. Leaves are simple, pale green in appearance, 5-7-angled, or with shallow lobes with rough surfaces. Stem is acutely five-angled with three or more hairy tendrils at the apex. Flowers are pale yellow, 4-5 cm in diameter, and unisexual. Male flowers are produced on stalks on unbranched elongated inflorescences, known as racemes, while female flowers are solitary and borne in the same leaf-axils as male flowers. Flowers are fragrant showing nocturnal opening. The unripe fruits of the plant are commercially grown for its unripe fruits which are sold as vegetables. The fibrous netting of the mature fruit is used as a sponge and are also used industrially as water filters. Different phytochemicals like sugar, starch, are present in the pollen grain which get mobilized on germination; thus playing an important role in germination and in the initial stages of pollen tube growth. During the germination of pollen grains, sucrose plays two pivotal roles, one is to provide energy source during the process of pollen tube formation and secondly maintains the proper osmoticum required for pollens. The failure of a pollen to germinate may indicate lack of sucrose within pollen grains and critical dependence on external supply. Another important element is boron which controls growth, permeability of cell membranes and helps in translocation of sugar. Boron also acts as cofactors of several enzymes controlling their activity [7]. Several researchers have investigated the impact of boron on development of reproductive organs and also pollen tube growth. Boron is believed to promote pollen germination by affecting H⁺-ATPase activity, which initiates pollen germination and tube growth [8].





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MATERIALS AND METHODS

Fresh flowers of *Luffa acutangula* L. were collected from Malda (Lat: N 25°7'57.77, Lon: E 88°9'36.32) and were then transferred to polythene zipper bags. Flowers are collected during the time of anthesis, i.e. in morning and in evening. At first the viability of pollen is tested by using acetocarmine stain in consecutive days. Acetocarmine is prepared by boiling an excess of carmine in 45% acetic acid (about a gram in 100 ml.) for 2 to 10 minutes. 45% acetic acid is used to dilute the solution to 2% carmine, thus 2% acetocarmine is prepared for examining pollen viability. Pollen viability were tested from the 1st day after collection to 10th day after collection. Solution of different concentrations of Sucrose, Boric acid (100ppm-500ppm) and the mixture of sucrose and boric acid were prepared. For combination of sucrose and boric acid, the boric acid concentration was kept constant (50 ppm) while the concentration of sucrose was increased from 100 ppm to 500 ppm. Then the fresh pollen samples were sown on cavity slides containing sucrose and boric acid solutions at above mentioned concentrations individually as well as in combination of both sucrose and boric acid from 1 hour to 10 hour duration respectively. Slides are then kept in petri dishes lined with moist filter papers at room temperature and examined under a microscope at low magnification (10x X 15x) after one hour interval to know the germinating percentage. A pollen grain is considered to be germinated, if the pollen tube length at least becomes twice greater than the diameter of the pollen grains [9]. All the values were recorded in triplicates and the values are graphically represented with statistical analysis.

RESULTS AND DISCUSSIONS

Pollen viability as a measure of pollen fertility clearly indicates that that percentage of viable pollens to that of non-viable pollens changes days after shedding from the anther locules. Also there is a marked difference in the number of viable pollens to that of non viable pollens collected during day time as well as during the morning. The percentage of viable pollens increases from first day of pollen collection to the eight day in a progressive manner and from ninth day onwards, there is a decline in the number of viable pollen grains. In case of pollen grains collected at night, the percentage of viable pollen grains were higher day wise as compared to that pollen grains collected in the night. However the number of viable pollen grains decline in a similar fashion to that of pollen grains collected during the day time. These results were depicted in Figure 1 (A &B). The *in vitro* pollen germination of *Luffa acutangula* L. also showed variation when treated for different time duration in sucrose and boric acid. The percent germination of pollens of *Luffa acutangula* L. treated with different strengths of sucrose solution showed a consistent rise with highest germination at 500 ppm treated for 8 hours duration with lowest germination recorded at 100 ppm of sucrose solution for 1 hour duration. However the germination percentage of pollens declined after 9 and 10 hours treatment respectively with sucrose in all the concentrations for sucrose.

Sucrose generally functions as a source of energy for the purpose of pollen tube growth and also maintains the proper osmoticum for pollens. The germination percentage of pollens of *Luffa acutangula* L. treated with different concentrations of boric acid also showed the similar trends with highest recorded at 500 ppm concentration for 8 hours duration followed by a similar decline in percent germination in subsequent hours. 100 ppm concentration for both sucrose and boric acid recorded lowest rate of pollen germination in all time durations. Boron can exert a protective effect in preventing excessive polymerization of sugars at sites of sugar metabolism [10]. Boron takes effective part in pollen germination and tube formation, therefore has a vital function in fertilization of flowering crops whereas deficiency of boron results in low pollen viability, poor pollen germination and reduced pollen tube growth [11]. In combination of sucrose and boric acid, the boric acid concentration was kept constant (50 ppm) while the concentration of sucrose was increased from 100 ppm to 500 ppm. It was observed that with gradual increase in the time of treatment of the pollen grains of *Luffa acutangula* L. with combination of sucrose and boric acid, the germination percentage increased consistently and was higher than the germination percentage when treated with sucrose and boric acid separately at same concentrations. However, the hour wise pollen germination percentage were optimum in 400 ppm + 50 ppm boric acid combination; but 500 ppm sucrose in combination with 50 ppm boric acid showed lower pollen germination under *in vitro* conditions. All the results were depicted in figure 2 to figure 5.





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Boron makes a complex with sugar and this sugar - borate complex is known to be capable of better translocation than non - borate, non - ionized sugar molecules [12]. It is believed that boron is directly involved in pectin synthesis and indirectly involved in development of the pollen tube membrane [13]. Sucrose and Boric acid also enhanced the pollen tube growth in case of *in vitro* pollen germination of *Saccharum sp.* [14]. Boron also influenced callose synthesis in growing pollen tubes on *in vitro* condition which was studied in *Hordeumvulgare* L. and also found in *Phoenix dactylifera* [15]. Thus, it may be concluded that boron along with sucrose plays an important role in pollen germination and tube development leading to successful fertilization in case of *Luffa acutangula* L.

REFERENCES

1. Stanley R G, Loewus FA (1994). Boron and myo-inositol in pollen pectin biosynthesis in Pollen Physiology and Fertilisation, Linskens HF (Ed.) North-Holl Publishing Company, Amsterdam. 128- 139.
2. Bhattacharya A, Mondal S and Mandal S (1997). *In vitro* pollen germination of *Delonixregia* (Boj.) Raf. Sci. and Cult. 63(5-6) 143-144.
3. Wang Q, Lu L, Wu X, Li Y and Lin, J (2003). Boron influences pollen germination and pollen tube growth in *Piceameyeri*. Tree Physiology, 23(5), 345 – 351.
4. Shivanna K R, Rangaswamy N S (1993). Pollen biology - A laboratory manual. Narosa publishing House, New Delhi. 45-67.
5. Ottavio E, Mulcahy D, Sari Gorla M and Mulcahy G B (1992). Angiosperm Pollen and Ovules, Springer –Verlag 211-223.
6. Heslop-Harrison J.S(1992). Cytological techniques to assess pollen quality. Sexual plant Reproduction. 41–48.
7. Holdaway-Clarke TL and Hepler PK (2003). Control of pollen tube growth: role of ion gradients and fluxes. New Phytology (159) 539-563.
8. Prajapati P P and Jain B K(2010). Effect of sucrose, boron, Calcium, magnesium and nitrate during *in vitro* pollen germination in *Luffaaegyptica* Mill. Prajna, (18), 5-8.
9. Gupta S, Bhattacharya, K N and Chanda S (1989). *In vitro* pollen germination of *Solanumsisymbriifolium* Lamk. Journal of Palynology, (25), 65-72.
10. Mortazavi S M H, Arzani A and Moieni AJ. (2010). Optimising storage and *in vitro* germination of date palm (*Phoenixdactylifera*) Pollen. Agricultural Science and Technology 12(2), 181-189.
11. Pal J K, Mandal S and Bhattacharya GN(1989). Studies on the *in vitro* pollen germination of the two varieties of *Buteamonosperma* (Lam.) Taub. Journal of Palynology, (25), 113-120.
12. Scott E G (1960). Effect of supra optimal boron levels on respiration carbohydrate metabolism of *Helianthusannus*. Plant Physiology, 35(5), 653- 661.
13. Gauch H G and Dugger W M (1953). The role of boron in the translocation of sucrose. Plant Physiology, (34) 457-466.
14. Moore P N and Jung, W L(1974). Studies in sugarcane pollen. *In vitro* germination of pollen. Phytol, International Journal of Experimental Botany, 32(2), 147-158.
15. Matsui T, Omasa K and Horie T (2000). Mechanisms of septum opening in anther of two rowed Barley (*Hordeumvulgare* L.). Annals of Botany, (86), 47- 51





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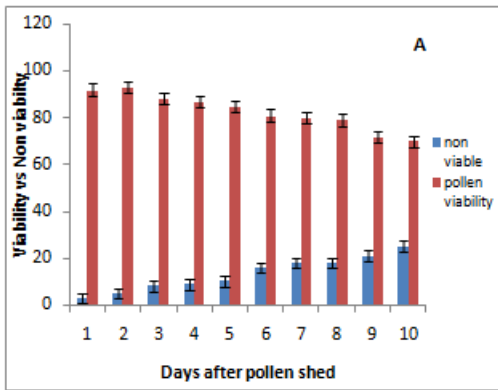


Fig 1- Viable vs Non viable pollen `A. Collected in the morning.

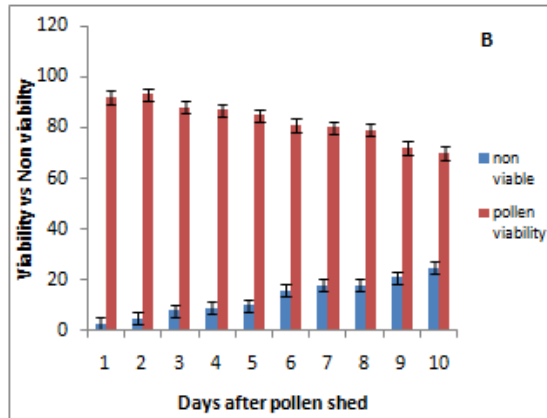


Fig 1- B. Collected in the evening

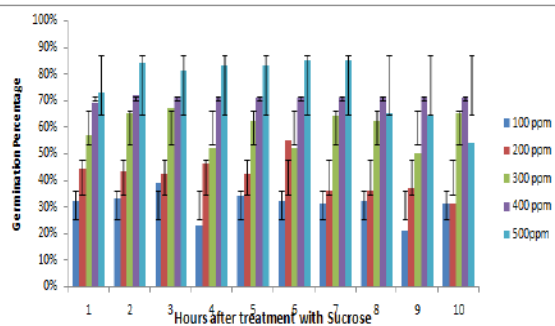


Fig 2- In vitro pollen germination of *Luffa acutangula* using different concentration of Sucrose

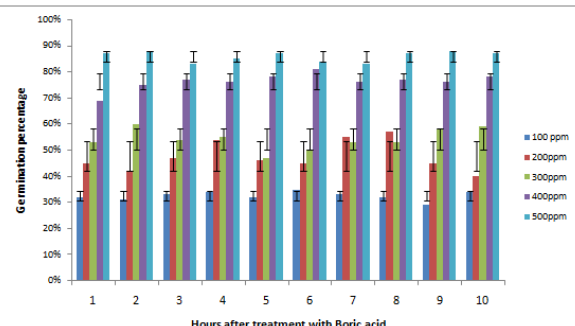


Fig 3- In vitro pollen germination of *Luffa acutangula* using different concentration of Boric Acid

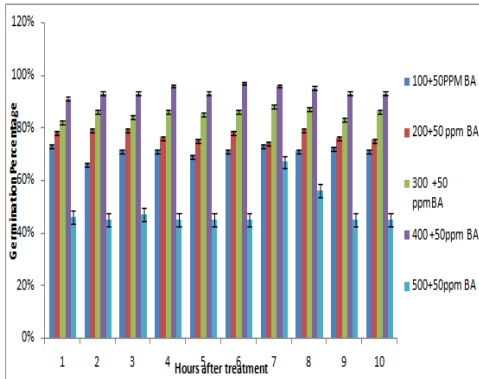


Fig 4 - In vitro pollen germination of *Luffa acutangula* using fixed concentration of Boric Acid and varying concentration of sucrose

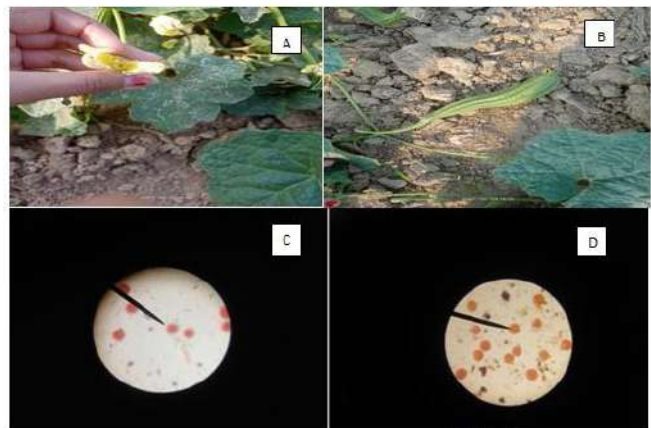


Fig 5- A-Flower of *Luffa acutangula*,B- Mature fruit of *Luffa acutangula*; C&D Viable and non viablepollen





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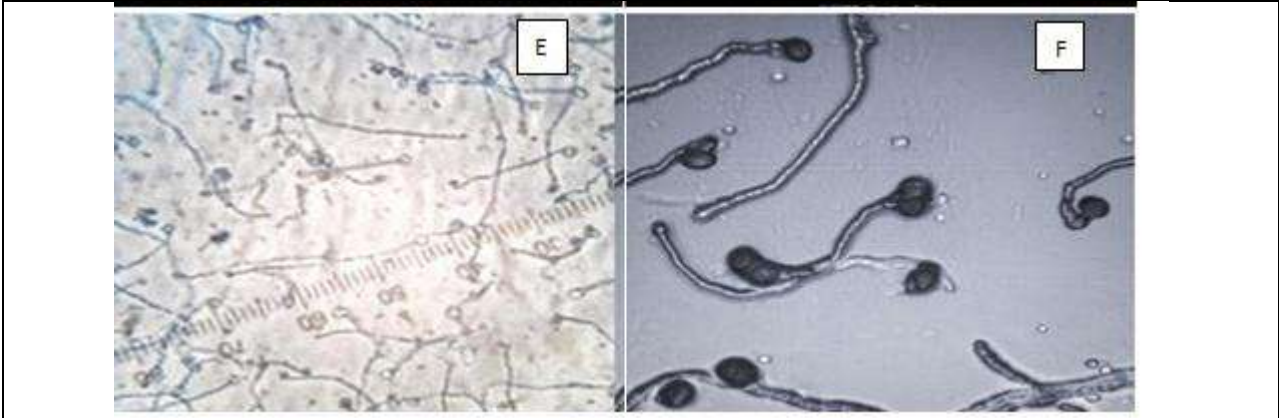


Fig 5- E& F-Germinated pollens showing pollen tube.





A Study on Sports Event Management in India

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ABSTRACT

An athletic tournament called the Asian Game was conceptualized in the 1950s and held in India. This is when the first structures for overseeing athletic activities were put in place. This tool was created with the goal of keeping track of sports and event management in India. Its creators wanted to raise awareness about the worrying trend in this industry and find some solutions. The objective of this study is to examine the intricacies of organizing athletic events in India by means of a comprehensive survey sent to a diverse group of people. The research aims to obtain knowledge about the preferences, habits, and levels of satisfaction among Indian sports lovers by investigating several themes such as favorite sports, event attendance, digital engagement, and environmental concerns related to sporting events. The study aims to find commonalities and differences in preferences across different demographics by asking questions on age, gender, location, and occupation. Along with this, the study investigates how the COVID-19 pandemic has affected people's inclination to go to live performances. It also draws attention to the opportunities and challenges that the current sports event management landscape presents. Stakeholders will be able to use the findings of this study to better organize and provide more accessible athletic events in the future. To do this, we will take a look at what makes event planning satisfying and what areas have room for improvement. In addition, the survey finds out how significant athletic events are culturally, looking at how they help bring people together and make them proud to be American. The results are meant to provide useful recommendations for marketers, policymakers, and event organizers so that people may get the most out of attending sporting events. This would make sure that the organizations can meet the evolving demands of Indian sports enthusiasts.

Keywords: Sports Event Management, India, Sports Preferences, Audience Engagement, Environmental Sustainability, Cultural Impact, Digital Solutions, Accessibility, COVID-19 Impact.



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INTRODUCTION

The field of sports event management in India encompasses a broad variety of core concepts that are necessary for the accurate planning, organization, leadership, promotion, and seamless execution of sporting events. These concepts are required for the successful implementation of sporting events. This multidisciplinary industry not only guarantees that athletic events are developed without any hiccups, but it also makes certain that sponsors, players, and fans are given with excellent hospitality. Because it blends the dynamic character of athletics with the strategic rigor of event management, this is the reason why it is so effective. These key components of sports management, which comprises a wide variety of tasks, include sports marketing, event marketing, finance, sports economics, and information management. Sports management also includes a range of other functions. Planning, organizing, directing, and controlling are the four pillars of management, and they are used to a variety of resources inside an organization, such as people, money, and data, in order to accomplish the goals that have been established. This is the foundation upon which it is built.

A wide variety of athletic competitions, ranging from traditional tribal games to championships that are known all over the world, are held in India. These numerous athletic events are absolutely extraordinary in terms of both their variety and their scope. [2] in the India has been the host or co-host of a number of notable athletic events in the past, including the Asian Games in 1951 and 1982, the Cricket World Cups in 1987, 1996, and 2011, and a great deal of other competitive sporting events. The significance of India's position in the international athletic arena is highlighted by these events. There are a great number of other sports that are given a lot of attention, including football, badminton, shooting, wrestling, tennis, and indigenous games like as chess, kho-kho, and snooker. However, cricket, the most popular sport, is held in high esteem by a great number of people. The Ranji Trophy, the Indian Super League, the Pro Kabaddi League, and the Indian Premier League (IPL) are just few of the well-known athletic competitions that demonstrate the wide variety of sports that are played in India and the passion that people have for them.

In the world of sports event management, the core lies in the conception and implementation of events that not only recognize sportsmanship and athletic talent, but also inspire community engagement and generate opportunities for sponsorship. These events are the essence of sports event management. Because of this, it is necessary to take a comprehensive strategy that takes into consideration the selection of the site, the logistics of the event, the scheduling, the management of risks, and the evaluation of the event after it has already taken place. During the planning stage, which is the first phase in the process, objectives are set, budgets are decided, and various logistical issues such as branding, guest lists, and sponsorships are completely detailed. During this stage, the process itself begins. When the planning phase is over, the marketing phase begins with the creation of strategies to boost the event's visibility and engagement through a number of channels. This phase begins after the planning phase has been completed. The local and national media, direct mail, and merchandising initiatives are all examples of these promotional channels.

The culmination of these efforts is presented on the day of the event, which requires rigorous preparation, ranging from rehearsals to site design, in order to ensure readiness for bad situations and to create smooth experiences for both participants and spectators. This preparation must not be overlooked. Indian firms that are recognized for their expertise in sports event management are illustrative of the vibrancy of the industry as well as the significant contribution it has made to the sports arena on both a national and international scale. For instance, Planet Jashn, Star TV, Sports Live, and IMG are all examples of organizations that fall under this category [2]. This study's mission is to analyze the complexities of sports event management in India, with the goal of exploring the possibilities and obstacles that are present within this dynamic business. The research will be conducted in order to explore the complexity of this industry. As well as gathering information on the preferences and points of view of spectators and participants, the objective of this study is to assess the impact that these mega-events have on cultural, economic, and social dimensions with the intention of evaluating the influence that these events have. Through conducting an



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exhaustive survey and analysis, the project intends to make a contribution to the greater discourse that is taking place about sports management and the significant role that it plays in the process of constructing India's athletic history. The purpose of the study is to provide insights that may be used to improve the efficiency and attractiveness of athletic events.

OBJECTIVES OF THE STUDY:

1. Conduct a comprehensive study to examine the inclinations, behaviors, and degrees of contentment among Indian sports aficionados with regards to athletic competitions.
2. Analyze the demographic disparities in sports choices, attendance trends, and online involvement.
3. Examine the influence of the COVID-19 epidemic on individuals' propensity to participate in live sports events.
4. Analyze the potential advantages and obstacles present in the current sports event management scenario in India.

REVIEW OF LITERATURE**Exploring the Dynamic Growth of India's Sport Events Market**

The Indian market for sporting events is on the verge of undergoing a dramatic transition, which is being driven by a convergence of factors that include evolving consumer behaviors as well as trends in the macroeconomic environment. Understanding the complexities of this market's growth trajectory is becoming increasingly important for stakeholders across the spectrum, including organizers and sponsors, as India prepares itself to become a blossoming hub for sporting events. The financial and participative components of the market are investigated in this phase of the research, which also provides a narrative that is driven by statistics regarding the market's development and its potential in the future. An assortment of graphs and data visualizations are offered in order to shed light on the dynamics of the market. Each of these graphs and visualizations serves to unpack a different aspect of the market's environment.

Figure 1 is a graphical representation of the revenue trajectory of the Sport Events market over a period of five years, beginning in 2024 and ending in 2028[1]. A positive growth prognosis is highlighted by the fact that the Compound Annual Growth Rate (CAGR) is projected to be 2.72 percent, which will result in a market volume of \$1.18 billion by the year 2028. This increased trend highlights the increasing potential for commercialization that exists within the ecosystem of Indian sports events. This visualization indicates that the number of users in the Sport Events industry is expected to increase to 42.2 million by the year 2028 [1]. Figure 2 illustrates the predicted rise of the user base. Additionally, it provides information on the user penetration rate, which is anticipated to remain stable at 2.9%. This indicates a consistent but moderate rise in the percentage of individuals who are actively purchasing tickets.

Figure 3 provides insights into the efficiency of revenue creation; this graph shows the average revenue per unit of purchase (ARPU) within the Sport Events market. The graph analyzes the income potential from each user, illustrating the value that is produced from individual participants over time[1]. The average revenue per user (ARPU) is anticipated to be \$25.40 in the United States.

The growth trajectory of the market for sporting events in India is supported by a number of important variables, including the following:

Customer Preferences and Lifestyle Trends: A shift towards more active, health-conscious lifestyles has spurred increased interest in sports and fitness activities. This shift is generating greater demand for sporting events, as individuals seek both participation in and spectation of sports competitions. The globalization of sports has also heightened interest in international sports events among Indian audiences.

Market Trends: The advent of social media and digital platforms has revolutionized access to information on upcoming sports events and streamlined the ticket purchasing process. This digital convenience has significantly boosted attendance. Furthermore, the rise of professional leagues across various sports has ignited fan interest and



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engagement.

Local Special Circumstances: India's rich sporting culture and history have nurtured a passionate fan base. Government initiatives aimed at promoting sports and investing in infrastructure have also played a crucial role in market growth.

Macroeconomic Factors: Economic growth and increased disposable incomes have made attending sports events more feasible for a broader segment of the population. The expansion of the middle class has widened the consumer base, presenting a lucrative opportunity for event organizers and sponsors.

COVID-19: effect sports industry worldwide:

[4] The epidemic caused by COVID-19 had a significant influence on the worldwide sports sector, resulting in both financial instability and the cancelation of events as well as the loss of jobs. The weakness of the sector was brought to light by the fact that revenue dropped to less than \$74 billion in the year 2020. For the purpose of mitigating losses, stakeholders have resorted to digital technologies and new initiatives, with a particular emphasis on digital engagement and athlete safety. As a result of the crisis, operational models were reevaluated, and an emphasis was placed on increased resilience. In spite of the difficulties, the sector is working toward a recovery and sustainable growth while concurrently gaining significant insights on flexibility and innovation. Although the globe is adjusting to a new normal, the sports industry is continuing its road towards recovery, which has been impacted by the dramatic repercussions of the epidemic throughout this time.

On March 18, 2020, Malaysia decided to implement a Movement Control Order, often known as an MCO. Because of this, sports activities that include large numbers of people congregating together, contact sports like rugby and football, and any and all indoor sporting events were prohibited as a result of MCO [3]. The FINA Diving GP Malaysia Leg, the Malaysia Open in May, the Malaysia International Age-Group Championships and the Sea Age-Group Championships, and a great number of other sporting events are among those that have been canceled or postponed as a result of this limitation. Consequently, the athletes' athletic development was hampered as a consequence of their participation in local and international contests with the intention of achieving their goal of qualifying for the Olympics. As a result, the purpose of this study is to evaluate the influence that COVID-19 has had on the career development of local athletes, as well as the emotional and physical repercussions that they have experienced as a result of experiencing restrictions on their participation in sports activities owing to the pandemic and the possibility of viral transmission during athletic events and training sessions.

Issues Concerning The Sports Industry:

[4] A number of challenges are affecting the Indian sports business, including financial limitations, a lack of available resources, mental obstacles, and the pressure to perform at a high level. Athletes are forced to pay for their own equipment and training because the government does not invest money on international sporting competitions. This creates a barrier, especially for those who are economically disadvantaged. In addition, while some cities have stadiums of exceptional quality, rural places do not have sufficient infrastructural capabilities. Despite the fact that established professions such as medicine and engineering are favored by society, attitudes about sports as a legitimate job option continue to be unfavorable. This way of thinking is a contributor to the high-performance pressure that athletes are currently experiencing, which frequently results in concerns related to mental health or drug scandals. Concerns over governance further exacerbate existing discrepancies, with charges of unfair selection procedures and post-success incentivization casting a shadow over help provided prior to the achievement of success. There are other obstacles that arise from cultural and religious reasons, such as the fact that certain religions are incompatible with certain attire standards. In spite of these obstacles, programs like as KheloIndia and the Target Olympic Podium Scheme are working to cultivate talent and enhance facilities. Additionally, the National Sports Development Fund is working to foster grassroots involvement across the country.



**Siddhant Mahambrey and Sathish Kumar****Improving the Sports Industry's Advantages:**

Recognizing the sports sector's potential beyond conventional roles is key to enhancing its advantages. For children who are having difficulty in the classroom and other marginalized populations, athletics not only provides a professional route but also a means of upward mobility. The general people are encouraged to lead better lifestyles by the natural focus on physical fitness in sports culture.

[16] The demographic dividend may become a reality because of India's young population and the positive impact that sports may have on them. Furthermore, athletics provide a stage upon which to address a wide range of socioeconomic concerns, with a focus on enabling women to question and subvert conventional wisdom.

Having a strong sports infrastructure does double duty: it opens up prospects for tourism and economic growth by allowing India to host international events, and it brings people together from all over the world via sports. Athletes from India, like Mary Kom and Saina Nehwal, inspire people at home and get recognition abroad, which fosters a sense of national unity. PV Sindhu's massive fan base is proof that athletics have the power to bring people of all backgrounds together, creating a bond that is both strong and beautiful.

Utilizing Technology and Innovation:

[6] In order to achieve better outcomes, encourage greater participation from fans, and provide a more enjoyable experience for all parties involved, the sports industry is increasingly relying on technical developments and innovative concepts. Programs that teach sports administration place a significant emphasis on keeping up with the latest technological innovations and learning how to make efficient use of these advancements. Among the cutting-edge practices that sports management professionals in India are employing to enhance growth, broaden their audience reach, and perhaps alter the sports sector are data analytics, virtual reality, and social media marketing. These are just a few instances of the practices that are among the most cutting-edge.

RESEARCH METHODOLOGY

In this study, we have adapted a qualitative research approach using a stratified sampling and we have chosen 104 sampling units. A method to research that is quantitative is utilized in this study in order to investigate the many components of sports event management in India and to determine the preferences and behaviors of the audience in relation to sporting events. For the purpose of gaining an understanding of the influence that various elements have on the levels of happiness and engagement experienced by attendance of sporting events, the aim is to gather and analyze data in a methodical manner.

Data Collection

For the purpose of this investigation, the major technique of data collecting consisted of the distribution of a questionnaire as a Google Form. This digital dissemination made it possible to collect responses from participants in India who belonged to a variety of demographic subgroups in a way that was not only efficient but also cost-effective. In order to ensure that respondents were able to readily comprehend and reply to the questions without demanding a significant amount of time commitments, the questionnaire was intended to be both thorough and accessible. The participants for the study were chosen using a method known as convenience sampling. The selection process targeted a broad set of persons throughout India who varied in terms of age, gender, and geographic area. This method of sampling allowed for the speedy gathering of data while simultaneously incorporating a wide range of opinions on the administration of sporting events and preferences. In order to get insights into the experiences and perspectives of individuals about sporting events in India, this study utilized a detailed questionnaire that was sent using Google Forms. The questionnaire was directed towards a wide population. It included topics such as demographic information, preferences about sports, event attendance and satisfaction, factors that influence attendance, the impact of COVID-19 on event participation, and the significance of environmental sustainability in the administration of sporting events. In order to uncover trends, preferences, and major variables that are impacting



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the sports event management sector in India, the data that was obtained from the survey will be examined using statistical software. In order to provide insights into enhancing sports event management techniques in order to boost attendee happiness and engagement, the study will concentrate on associating demographic parameters with preferences and behaviors.

DEMOGRAPHIC ANALYSIS

In table 1, there were 104 valid responses. The majority of respondents (32.7%) rated a factor as "1", followed by 26.9% rating it as "2", 25.0% as "3", and 15.4% as "4". The cumulative percentages show the proportion of responses up to each category.

In this gender frequency distribution table, there were 104 valid responses. The majority of respondents (51.0%) identified as "1" (presumably representing one gender category), while 49.0% identified as "2" (presumably another gender category). The cumulative percentages demonstrate the proportion of responses up to each category, indicating an even split between the two gender categories.

ANALYSIS AND FINDINGS**ANOVA ANALYSIS**

The ANOVA test for Event Management Satisfaction yielded a non-significant result ($p = .170$), suggesting no significant difference in satisfaction levels between groups. The between-groups variation (2.317) compared to the within-groups variation (123.674) indicates that most of the variability in satisfaction scores is within groups rather than between them. With a p-value above the typical significance threshold of .05, there's insufficient evidence to reject the null hypothesis, indicating that any observed differences in satisfaction levels are likely due to random variability rather than systematic differences between groups.

The ANOVA test for COVID-19 Impact yielded a significant result ($p < .001$), indicating a significant difference in the impact of COVID-19 between groups. The between-groups variation (5.021) compared to the within-groups variation (42.364) suggests that a substantial proportion of the variability in COVID-19 impact scores is attributable to group differences rather than random variability. With a p-value below the typical significance threshold of .05, there's strong evidence to reject the null hypothesis, suggesting that there are systematic differences in the impact of COVID-19 across groups. The ANOVA results show a non-significant F-value ($F = 1.283, p > 0.05$), suggesting no significant difference in satisfaction levels across groups. This indicates that perceptions of fairness and transparency in sports management are consistent among respondents. However, further qualitative analysis may be necessary to understand specific areas of concern or improvement within sports management practices.

INDEPENDENT SAMPLE T-TEST

In the Independent Samples T-Test for Event Management Satisfaction, Levene's Test for Equality of Variances yielded a significant result ($F = 25.210, p < .001$), indicating unequal variances between groups. Therefore, both equal and unequal variances were examined for the t-test. When assuming equal variances, the t-test showed a non-significant result ($t = -1.382, df = 102, p = .085$), suggesting no significant difference in event management satisfaction between groups. The mean difference was .170, with a standard error of .216. The 95% confidence interval ranged from -.727 to .130. When not assuming equal variances, similar results were obtained ($t = -1.372, df = 86.890, p = .087$), indicating no significant difference in event management satisfaction between groups. The mean difference and confidence interval remained consistent with the previous test.

In the Independent Samples T-Test for Favorite Sport, Levene's Test for Equality of Variances yielded a marginally significant result ($F = 3.917, p = .050$), indicating a potential difference in variances between groups. Thus, both equal and unequal variances were examined for the t-test. When assuming equal variances, the t-test showed a non-significant result ($t = -1.030, df = 102, p = .153$), indicating no significant difference in the mean scores of Favorite Sport between groups. The mean difference was .305, with a standard error of .215. The 95% confidence interval



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ranged from -.648 to .205. Similarly, when not assuming equal variances, the t-test produced a non-significant result ($t = -1.026$, $df = 96.907$, $p = .154$), indicating no significant difference in mean scores of Favorite Sport between groups. The mean difference and confidence interval remained consistent with the previous test.

CORRELATION

The correlation between COVID-19 Impact and Environmental Sustainability Importance was found to be positive but weak, with a Pearson correlation coefficient of .107 ($p = .281$). This indicates a negligible relationship between the impact of COVID-19 and the importance individuals place on environmental sustainability. With both variables having a sample size of 104, the lack of statistical significance suggests that changes in COVID-19 impact do not significantly influence perceptions of environmental sustainability importance among respondents. The correlation between Event Management Satisfaction and Environmental Sustainability Importance was found to be positive and moderately strong, with a Pearson correlation coefficient of .442 ($p < .001$). This indicates a significant positive relationship between individuals' satisfaction with event management and the importance they place on environmental sustainability. With both variables having a sample size of 104, the correlation is highly significant at the 0.01 level, suggesting that higher levels of satisfaction with event management tend to be associated with greater importance placed on environmental sustainability among respondents.

The correlation between Favorite Sport and Live Event Attendance was found to be positive and strong, with a Pearson correlation coefficient of .643 ($p < .001$). This indicates a significant positive relationship between individuals' favorite sport and their attendance at live events. With both variables having a sample size of 104, the correlation is highly significant at the 0.01 level, suggesting that individuals who have a favorite sport tend to be more likely to attend live events related to that sport.

FINDINGS

The study on sports event management in India conducted by Hindustan Institute of Technology & Science, Chennai, aimed to comprehensively analyze various aspects of organizing athletic events in India. The research utilized a survey-based approach to gather insights into the preferences, habits, and levels of satisfaction among Indian sports enthusiasts. The study covered several themes, including favorite sports, event attendance, digital engagement, environmental concerns related to sporting events, and the impact of the COVID-19 pandemic on live event participation. Additionally, the research explored demographic disparities in sports choices, attendance trends, and online involvement, along with assessing the potential advantages and obstacles present in the current sports event management landscape in India. The demographic analysis revealed interesting insights into the respondent characteristics. In terms of age distribution, the majority of respondents fell into the younger age categories, with 32.7% in the youngest category and 26.9% in the next age group. This suggests a significant interest in sports events among younger individuals. Regarding gender distribution, the sample was evenly split between male and female respondents, indicating a balanced representation of gender perspectives in the study.

The study employed ANOVA tests to analyze differences in event management satisfaction and the impact of COVID-19 across different groups. The ANOVA test for event management satisfaction showed a non-significant result, suggesting no significant difference in satisfaction levels between groups. However, the ANOVA test for COVID-19 impact yielded a significant result, indicating systematic differences in the impact of COVID-19 across groups. This finding underscores the need for tailored approaches to address the varied effects of the pandemic on event participation. Furthermore, the study utilized independent samples T-tests to examine differences in event management satisfaction and favorite sports between groups. Both tests resulted in non-significant findings, indicating no significant differences in satisfaction levels or favorite sports preferences between groups. These results highlight the consistent nature of event management satisfaction and sports preferences across different demographic segments.



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The correlation analysis revealed interesting relationships between key variables. The correlation between event management satisfaction and environmental sustainability importance was found to be positive and moderately strong, indicating a significant positive relationship between satisfaction with event management and the importance placed on environmental sustainability. Similarly, the correlation between favorite sport and live event attendance was positive and strong, suggesting a significant positive relationship between individuals' favorite sports and their attendance at live events. Overall, the findings of the study shed light on various aspects of sports event management in India. The demographic analysis highlighted the diverse nature of the respondent population, with a significant interest in sports events among younger individuals. The ANOVA and T-test results underscored the consistent nature of event management satisfaction and sports preferences across different groups, while the correlation analysis revealed significant relationships between key variables such as event management satisfaction, environmental sustainability importance, favorite sports, and live event attendance. These findings provide valuable insights for stakeholders in the sports event management industry, including marketers, policymakers, and event organizers. By understanding the preferences, habits, and satisfaction levels of Indian sports enthusiasts, stakeholders can better organize and provide more accessible athletic events in the future. Additionally, the findings can inform strategies for addressing challenges such as the impact of the COVID-19 pandemic and promoting environmental sustainability in sports event management practices.

CONCLUSION

In conclusion, the study on sports event management in India conducted by Hindustan Institute of Technology & Science, Chennai, provided valuable insights into various aspects of organizing athletic events in the country. Through comprehensive surveys and statistical analyses, the research examined preferences, habits, and levels of satisfaction among Indian sports enthusiasts, alongside demographic disparities and the impact of external factors such as the COVID-19 pandemic. The findings highlighted consistent levels of event management satisfaction and sports preferences across different demographic segments, emphasizing the need for tailored approaches in addressing challenges and promoting engagement. Moreover, significant positive relationships were observed between event management satisfaction and environmental sustainability importance, as well as between favorite sports and live event attendance. These insights offer valuable guidance for stakeholders in the sports event management industry, enabling them to enhance event organization, improve attendee satisfaction, and address evolving demands effectively. By leveraging these findings, marketers, policymakers, and event organizers can develop strategies that prioritize sustainability, inclusivity, and resilience, ensuring the continued growth and success of sports events in India. Additionally, the study underscores the importance of ongoing research and analysis in driving innovation and progress in the sports event management landscape.

REFERENCES

1. Statista. (n.d.). Sport Events - India. Retrieved from <https://www.statista.com/outlook/dmo/eservices/event-tickets/sport-events/india>
2. Tiwari, U., & Tiwari, D. (2020). Sports Event Management in India. *International Journal of Fitness, Health, Physical Education & Iron Games*, 7(2), July 2020 to Dec 2020. ISSN 2349 – 722X.
3. Daley, P., Ho, K., Greyling S., & Haley, G. (2020). COVID 19 - Hong Kong, Singapore and Malaysia: Postponement or cancellation of sports events - Force majeure clauses and other relief. <https://www.bcplaw.com/en-GB/insights/covid-19-hong-kong-singapore-and-malaysia-postponement-or-cancellation-of-sports-events-force-majeure-clauses-and-other-relief.html>
4. Keshkar, S., & Karegar, G. A. (2022). Effect of the COVID-19 pandemic on the sports industry. In M. H. Dehghani, R. R. Karri, & S. Roy (Eds.), *COVID-19 and the Sustainable Development Goals* (pp. 123–157).
5. Keshkar S., Afsharpour M. Faculty of sports sciences. AllamehTabataba'i University; 2019. Water management in Tehran's sports complexes under the conditions of the national water crisis. M.A. Thesis.





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6. Emery, Paul R. "Bidding to host a major sports event: The local organising committee perspective." *International Journal of Public Sector Management* 15.4 (2002): 316-335.
7. Bull, C., & Lovell, J. (2007). The impact of hosting major sporting events on local residents: An analysis of the views and perceptions of Canterbury residents in relation to the Tour de France 2007. *Journal of Sport & Tourism*, 12(3-4), 229-248.
8. Kim, A., Choi, M., & Kaplanidou, K. (2015). The role of media in enhancing people’s perception of hosting a mega sport event: The case of Pyeongchang’s Winter Olympics bids. *International Journal of Sport Communication*, 8(1), 68-86.
9. Ma, S. C., Ma, S. M., Wu, J. H., & Rotherham, I. D. (2013). Host residents' perception changes on major sports events. *European Sport Management Quarterly*, 13(5), 511-536.
10. "Aims and Objectives," Sports Authority of India, October 29, 2013, www.sportsauthorityofindia.nic.in/index1.asp?ls_id=91.
11. "Department of Sports: Scheme of Human Resources Development in Sports," Ministry of Youth Affairs and Sports, May 22, 2019, <https://yas.nic.in/sports/scheme-human-resources-development-sports-0>.
12. Gillen N. Nancy Gillen: how will coronavirus impact women's sports? 2020. <https://www.insidethegames.biz/articles/1093591/how-will-the-pandemic-affect-women-sports>
13. Nikhilesh Bhattacharya, "India’s Olympic Program Under Spotlight Again," *New York Times*, accessed August 13, 2012, <https://india.blogs.nytimes.com/2012/08/13/indias-olympic-program-under-spotlight-again/>.
14. "Centre of Excellence Scheme–COE," Sports Authority of India, November 10, 2014, http://sportsauthorityofindia.nic.in/index1.asp?ls_id=627.
15. Mukherjee, Arpita. "Sports Retailing in India: Opportunities, Constraints and Way Forward." Working Paper No. 250, Indian Council for Research on International Economic Relations (ICRIER), 2010 .
16. Gupta, V. (2021). Sports Event Management Benefits & Issue. *Social Science Journal for Advanced Research*, 1(3), 57-62. DOI: 10.54741/ssjar.1.3.9. Retrieved from www.ssjar.org.

Table 1: Frequency distribution of Age

	Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	34	32.7	32.7
	2	28	26.9	59.6
	3	26	25.0	84.6
	4	16	15.4	100.0
Total	104	100.0	100.0	

Table 2: Frequency distribution of Gender

	Frequency	Percent	Valid Percent	Cumulative Percent	
Valid	1	53	51.0	51.0	51.0
	2	51	49.0	49.0	100.0
	Total	104	100.0	100.0	

Table 3: ANOVA TEST - Event Management Satisfaction

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2.317	1	2.317	1.911	.170
Within Groups	123.674	102	1.212		
Total	125.990	103			





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Table 4: ANOVA TEST -COVID19 IMPACT

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	5.021	1	5.021	12.088	<.001
Within Groups	42.364	102	.415		
Total	47.385	103			

Table 5: ANOVA TEST - How would you rate your overall satisfaction with the current state of sports management in terms of fairness and transparency?

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	7.392	3	2.464	1.283	.288
Within Groups	122.887	64	11.920		
Total	130.279	67			

Table 6: Independent Sample T Test

		Levene's Test for Equality of Variances		t-test for Equality of Means							
		F	Sig.	t	df	Significance		Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						One-Sided p	Two-Sided p			Lower	Upper
Event Management Satisfaction	Equal variances assumed	25.210	<.001	-1.382	102	.085	.170	-.299	.216	-.727	.130
	Equal variances not assumed			-1.372	86.890	.087	.174	-.299	.218	-.731	.134

Table 7: Independent Sample T Test

		Levene's Test for Equality of Variances		t-test for Equality of Means							
		F	Sig.	t	df	Significance		Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						One-Side	Two-Side			Lower	Upper





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						d p	d p				
Favorite Sport	Equal variances assumed	3.917	.050	-1.030	102	.153	.305	-.222	.215	-.648	.205
	Equal variances not assumed			-1.026	96.907	.154	.307	-.222	.216	-.650	.207

Table 8: Correlations

		COVID-19 Impact	Environmental Sustainability Importance
COVID-19 Impact	Pearson Correlation	1	.107
	Sig. (2-tailed)		.281
	N	104	104
Environmental Sustainability Importance	Pearson Correlation	.107	1
	Sig. (2-tailed)	.281	
	N	104	104

Table 9: Correlation

		Event Management Satisfaction	Environmental Sustainability Importance
Event Management Satisfaction	Pearson Correlation	1	.442**
	Sig. (2-tailed)		<.001
	N	104	104
Environmental Sustainability Importance	Pearson Correlation	.442**	1
	Sig. (2-tailed)	<.001	
	N	104	104

**. Correlation is significant at the 0.01 level (2-tailed).

Table 10: Correlation

		Favorite Sport	Live Event Attendance
Favorite Sport	Pearson Correlation	1	.643**
	Sig. (2-tailed)		<.001
	N	104	104
Live Event Attendance	Pearson Correlation	.643**	1
	Sig. (2-tailed)	<.001	
	N	104	104

**. Correlation is significant at the 0.01 level (2-tailed).





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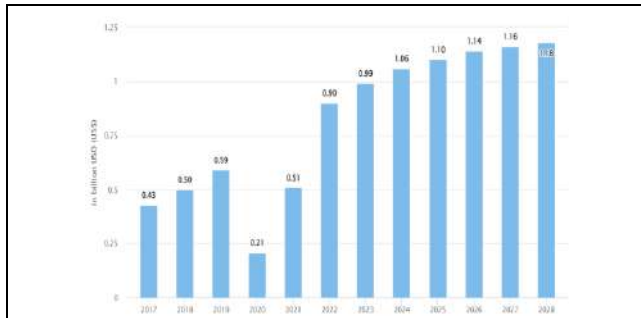


Fig 1: Projected Revenue Growth (2024-2028)

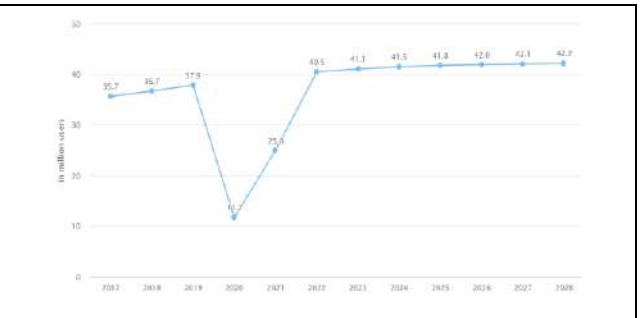


Fig 2: User Growth Forecast (2024-2028)

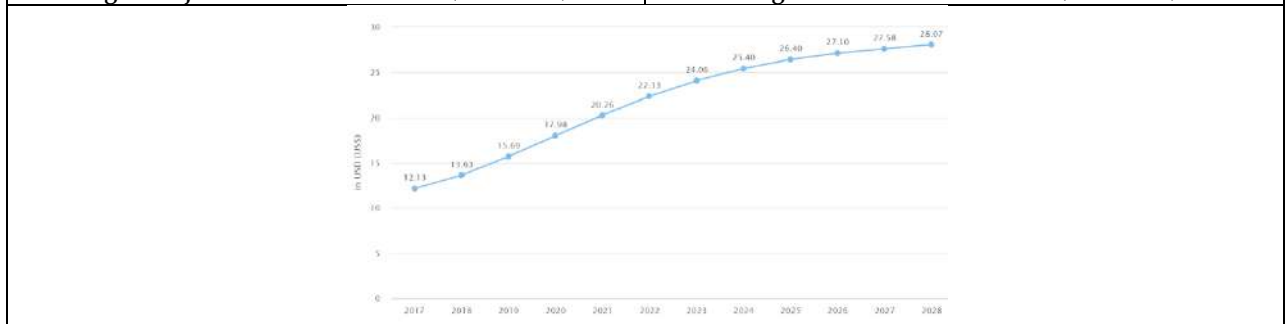


Fig 3: Average Revenue Per User (ARPU) Analysis





Phytoplankton Diversity in Relation to Physico-Chemical Parameters of Periyakulam Pond, Azhigiyapandipuram

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ABSTRACT

Physico-chemical parameters and Diversity of phytoplankton of fresh water pond of periyakulam, Azhigiyapandipuram have been studied during October 2020-2021. A total of 125 algal taxa were observed in the study period. The class Chlorophyta was 22 genera with 56 species, the class Bacillariophyta was 16 genera with 37 species, the Cyanophyta was 12 genera with 28 species and the class of Euglenophyta was 3 genera and 4 species were recorded. To know the variation in periodicity and distribution of phytoplankton, various physico-chemical parameters of pond water have been observed.

Keywords: Physico-chemical parameters, Phytoplankton.



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INTRODUCTION

Water is life. No life can exist without water, water resources are of critical importance to both natural ecosystem and human development. It is absolutely essential for domestic purposes for cleaning, cooking, bathing, and carrying away wastes, and in agriculture for irrigation, power generation, industries, navigation, propagation of wild life, fisheries, recreation, aesthetics etc. Water quality is determined by various physico-chemical and biological parameters. These parameters change generally due to many factors like source of water, type of pollution, seasonal fluctuations and adjacent human intervention that directly or indirectly affect its quality and consequently its suitability for the distribution and production of fish and other aquatic animals. Several researchers have reported the status of water bodies (lentic and lotic) after receiving various kinds of pollutants altering water quality characteristics (physical, chemical and biological). All living organisms have tolerable limits of water quality parameters in which they perform optimally. A sharp drop or an increase within these limits has adverse effects on their body functions [1]. Phytoplanktons are the primary producers forming the first trophic level in the food chain. Diversity of planktonic organisms is quite high in fertile standing water bodies. Phytoplankton are the productive base of the food chain in freshwater ecosystems and healthy aquatic ecosystem is dependent on its physical, chemical and biological characteristics [2]. Increased growth of certain groups of phytoplankton especially blue green algae that decrease phytoplankton diversity is a key factor in the determination of water quality in reservoir. Thus, understanding the process of phytoplankton variation can be particularly useful in water quality evaluation, improvement and management decisions. Phytoplanktons are first link in nearly all aquatic food chain [3], without phytoplankton, the diversity and abundance of aquatic life would be impossible. Phytoplankton provide, food for a tremendous variety of organisms, including zooplankton (microscopic animal), bivalve molluscan, shellfish (mussels, oysters, scallops and clams), and small fish. Wu, 1984 [4] has described a relation between aquatic organisms to the degree of pollution and introduced the concept of bio-indicators of pollution in their saprobic system. However, excessive growth and accumulation of phytoplankton as blooms lead to destruction of any water body resulting in dire consequences. The objective of the present study is to analyse the physico chemical parameters and the phytoplankton diversity of the selected pond.

MATERIALS AND METHODS

Monthly phytoplankton samples were collected, fixed in 4% formalin and number of cells/ml was observed. These were identified by using standard literatures [5,6,7]. The following physico-chemical parameters were observed using standard methods. Surface water temperature, pH of the water, dissolved oxygen, biological oxygen demand, nitrite content, chloride, alkalinity.

RESULTS AND DISCUSSION

Waters in nature is not pure and contains dissolved salts nutrients etc. The physico-chemical properties of experimental ponds are represented in the table 1 and figure 1. Temperature is a physical factor in controlling the fluctuation of plantation and functioning of aquatic ecosystem. The water temperature ranged between minimum value was (22.5°C) and maximum value was (26.4°C). The maximum water temperature showed during summer in all the ponds. The present observation was supported by the findings of verma et al.2011 [8] in few ponds of Kanyakumari district. The pH is a limiting factor and works as an index of general environmental condition. During the study period the pH varied from minimum value was (5.83) and maximum value was (7.40). The maximum pH value observed in the month of February. Similar observation was recorded byPuri et al., 2010 [9]. High value of pH was recorded in the summer season because of due to utilization of bicarbonate and carbonate buffer system. The Biological Oxygen Demand (BOD) is a parameter that enables the determination of relative oxygen requirements especially of waste water, polluted waters and effluents. The present study recorded high values during the month of March. The maximum values were recorded during summer season. The result was confirmed with the findings of



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Verma et al., 2011 [8]. Dissolved Oxygen was found maximum of (7.49mg/l) in the month of March and minimum value of (6.69mg/l) in the month of October. This result was in agreement with the result of Sharma et al., 2017[10]. Water temperature is inversely proportional to the Dissolved Oxygen concentrations. This may be due to the discharge of huge quantities of waste water accompanied by increasing inorganic matter and the results are inconsistency with the earlier. Highest level of chloride concentration was observed during the month of March 2018, during summer when the pond has very low level of water. A similar increase was reported by Verma et al., 2011 [8]. They also stated that the high chloride concentration of the pond water may be due to high rate of evaporation or due to organic waste of animal origin. Nitrite iron is the common form of combined nitrogen found in natural waters. High concentration of nitrite in water helps better growth of phytoplankton and the permissible limit is 50 mg/l. Nitrite concentration varied from maximum value was (0.27mg/l) and minimum value was (0.07mg/l). The present observation is the same with the findings of Johnson et al., 2003[11]. Total alkalinity is due to salts of weak acids and bicarbonates. The highly alkaline water is not possible. Total alkalinity was observed maximum value was (97.20mg/l) and minimum value was (61.12mg/l). The alkalinity values maximum during summer season. Similar findings were reported by Shinde et al., 2011 [12]. According to Kaur et al.,2000[13] high alkalinity values are the indicators of eutrophic nature. Increased alkalinity was resulted due to the increase in free CO₂. Higher levels of alkalinity resulted in the present observations was mainly due to agricultural runoff and surface in the month of March (Azhiyapandipuramperiyakulam).

Phytoplankton

Phytoplankton are autotrophs and belonging to first trophic level in the food chain. In the present study total of 125 phytoplankton species during the study period. phytoplankton contributed 44.8% of chlorophyta, 29.6% of Bacillariophyta, 22.4% of Cyanophyta, 3.2% of Euglenophyta. Among the 4 family, Chlorophyta contributed maximum percentage and Euglenophyta contributed minimum percentage. The class Chlorophyta was 22 genera with 56 species, the class of Bacillariophyta was 16 genera with 37 species, the cyanophyta was 12 genera with 28 species and the class of Euglenophyta was 3 genera and 4 species were recorded. The distribution is noted in descending order as Chlorophyceae>Bacillariophyceae>Cyanophyceae>Euglenophyceae. The percentage contribution showed Chlorophyta occupying dominant position of phytoplankton in 44.8% with maximum production in summer season causing the pond water due to the abundance of Chlorophyceae and minimum in the winter season. This result was correlated with the result of Devika et al., 2006 [14]. From the present study, it is clear that Chlorophyceae showed a positive correlation with dissolved oxygen, nitrite and transparency. This finding was in accordance with the earlier works of Das, 2002[15]. Presence of *Spirogyra*, *Navicula*, *Chlorella* and *Microcystis* through in low densities indicated the slightly organic pollution in ponds [16].

CONCLUSION

In conclusion the present study revealed that the distribution and population density of phytoplankton species depend upon the physico-chemical parameters of the environment. It is clear from the result that the pond is mesotrophic and aging towards eutrophication. Hence the measures should be taken to minimize the fresh water pollution by preventing washing of clothes and other human activities. In addition, the data generated in the form of memoir are essential so that the information may be used as the decision maker for conservation and effective utilization of water bodies.

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REFERENCES

1. Baleta, FN and Bolanos, JM, 2016, 'Phytoplankton identification and water quality monitoring along the fish-cage belt at Magat dam reservoir, Philippines', International Journal of Fisheries and Aquatic Studies, vol.4, no.3, pp.254-260.
2. Venkatesharaju, K, Ravikumar, P, Somashekar, RK, 2010, 'Bacteriological Investigation on the river Cauvery of Kollegal Stretch in Karnataka', Journal of Science Engineering and Technology, vol.6, no.1, pp. 50-59.
3. Babatunde, MM, Balogun, JK, Oladimeji, AA, Auta, J and Balarabe, ML, 2014, 'Variations of phytoplankton abundance and species composition in Kudiddiffi – Kubanni stream, Hanwa –Makera, Zaria, Nigeria. Implication for water quality', International Journal of Advance Scientific Technical Research.
4. Wu, JT, 1984, 'Phytoplankton as a bioindicator of water quality in Taipei', Botanical Bulletin of Academia Sinica, pp.25-214.
5. Prescott, GM, 1978, 'The freshwater algae, C. Brown Company Publication Dubuque, Iowa.
6. Fritsch, FE 1945, The structure and reproduction of algae, vol.II, Cambridge University Press, London.
7. Anand, N, 1998, Indian fresh water microalgae. B. Singh and M.P. Singh, Dehradun, India.
8. Verma, D.K. Chandawat and H.A. Solanki (2011), 'Seasonal variation in physico-chemical and phytoplankton analysis of Kankaria lake, Life science leaflets, vol.19, pp. 842-854.
9. Puri, M.K.N.Yenkie, D.G.Battalwar, NileshV.Gandhare and Dewanand B. Dhanorkar (2010), 'Study and interpretation of physico-chemical characteristic of lake water quality in Nagpur City (India), <http://www.rasayanjournal.com>, vol.3, no.4, pp.800-810.
10. Sharma, K.K., NitashaSawhney and SarbjeetKour (2017), Some limnological investigations in Ban Ganga stream, Katra, Jammu and Kashmir State. J.Aqua. Biol., vol.22, no.1, pp. 105-109.
11. Johnson, MEC, Rani, SP, and Shailey, AK 2003, 'Ecological studies on a Chlorococcus bloom. Geobioscience, vol.30, pp.39-42.
12. Shinde, SE, Pathan, TS, Raut, KS, More, PR & Sonaware, DL, 2011, 'Seasonal variations in physico-chemical characteristics of Harsool – Savangi Dam, District, Aurangada, India' 'The Ecoscan, vol.4, no.1, pp.37-44.
13. kaur, H, Bath, KS, Mander, G, and Jerath, N 2000, 'Physico-chemical status of Kanjili Wetland (Punjab) India', Journal of Environmental and Pollutions, vol.7, no. 1, pp.39-42.
14. Devika, R, Rajendran, A, and Selvapathy, P 2006, 'Variation studies on the physico-chemical and biological characteristics at different depths in model waste stabilisation tank, 'Pollution Research, vol.24, pp.771-774.
15. Das, AK 2002, 'Phytoplankton primary production in some selected reservoirs of Andra Pradesh, Geobioscience, vol.29, pp.52-57.
16. Shekar, RT, Kiran, BR, Puttaiah, ET, Shivaraj, Y and Mahadeven, KM 2008. Phytoplankton as index of water quality with reference to industrial pollution'. Journal of Environmental Biology, vol.29, pp.233-236.

Table:1 Physico-chemical parameters recording in the experimental pond during October -2020 to March-2021.

Month	Temperature	pH	DO	BOD	Alkalinity	Chloride	Nitrite
October	25.8	6.35	6.69	2.34	78.96	2.4	0.14
November	25.1	6.83	6.92	1.96	67.63	2.1	0.19
December	24.8	7.40	6.83	1.84	61.12	1.6	0.23
January	22.5	6.13	7.11	1.76	91.02	1.4	0.27
February	23.9	6.09	7.28	2.44	96.26	2.8	0.12
March	26.4	5.83	7.49	2.67	97.20	3.2	0.07





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Table 2: Distribution of phytoplankton in experimental pond (October 2020 to March 2021)

S.No	Name of phytoplankton	October	November	December	January	February	March
	Chlorophyceae						
1	<i>Arthodesmis gibberulus</i>	+	-	+	+	+	-
2	<i>Chlorochytrium lemnae</i>	+	++	++	+	+	+
3	<i>Cladophora glomerata</i>	-	+	+	-	-	+
4	<i>Closterium cyanthia</i>	+	-	+	++	+	+
5	<i>Closterium kuetzingii</i> Breb.	++	+	++	+	+	-
6	<i>Closterium leibleinii</i> Bory, Ehrenb.	-	-	+	++	-	+
7	<i>Closterium lineatum</i> , Her	+	+	-	-	+	+
8	<i>Closterium</i> sp.	-	-	+	+	++	-
9	<i>Coelastrum microsporum</i>	+	+	-	+	++	-
10	<i>Coelastrum reticulatum</i> (Dang.) Senn.	+	-	+	+	+	+
11	<i>Cosmarium cucurbitinum</i>	-	++	-	-	++	+
12	<i>Cosmarium pseudo retusum</i>	+	-	+	+	-	-
13	<i>Cosmarium</i> sp	-	-	-	+	++	+
14	<i>Cosmarium subscoticum</i>	+	+	-	+	+	-
15	<i>Crucigenialauter bornii</i> Sch.	-	+	+	-	-	-
16	<i>Cylindrocystis</i> sp	+	-	+	-	+	+
17	<i>Hydrodictyon reticulam</i>	++	+	+	-	+	-
18	<i>Microsteria radiosa</i> Turner	-	+	-	+	-	++
19	<i>Mougeotia sphaerocarpa</i> Wolle	+	-	+	-	++	-
20	<i>Oedogonium figuratum</i>	+	++	-	-	++	-
21	<i>Oedogonium globosum</i>	-	+	-	+	-	++
22	<i>Oedogonium giganteum</i> Kutzing	-	-	+	++	-	-
23	<i>Oedogonium globosum</i> Nordst.	-	++	+	+	+	-
24	<i>Oedogonium inclusum</i> Hirn.	+	+	-	-	+	++
25	<i>Oedogonium microgonium</i> Prescott	-	-	+	+	+	-
26	<i>Oedogonium porrectum</i> Nardst.	+	++	-	++	-	+
27	<i>Oedogonium</i> sp	+	++	-	++	-	+
28	<i>Oedogonium subareolatum</i> Tiffany	-	-	-	+	+	++
29	<i>Pediastrum radiatum</i>	-	+	+	-	-	+
30	<i>Pediastrum duplex</i>	+	++	-	+++	+	-
31	<i>Pediastrum duplex varreticulatum</i> Lagerh.	+	-	-	++	+	+
32	<i>Pediastrum gracillium</i>	+	+++	+	+	-	+
33	<i>Pediastrum simplex</i>	-	-	+	-	+	+
34	<i>Pediastrum</i> sp	+++	+	-	+	-	-
35	<i>Pediastrum tetras</i>	-	-	+	-	+	+
36	<i>Pediastrum tetras var. tetraodon</i>	+	+	+++	-	-	-
37	<i>Pleurotaenium</i> sp	+	+	+	+	+	++
38	<i>Rhizoclonium hieroglyphicum</i> (Ag.) Kutz.	-	+	-	-	+	-
39	<i>Rhizoclosium</i> sp	+	++	-	++	-	-





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40	<i>Scenedesmus arcuatus</i> var. <i>capilatus</i> G.M.Smith	+	-	+	-	+	++
41	<i>Scenedesmus armatus</i> var. <i>bicaudatus</i>	-	+	+	-	+	-
42	<i>Scenedesmus bijugatus</i> Turp.	+	+	-	++	-	+
43	<i>Scenedesmus bijugatus</i> var. <i>bicellularis</i> Chodat.	+	-	-	+	-	+
44	<i>Scenedesmus bijugatus</i> var. <i>graevenitzii</i> Bern	-	+	+	-	+	-
45	<i>Scenedesmus dimorphus</i> (Turp.) Kuetz.	-	+	-	+	-	++
46	<i>Scenedesmus hystrix</i> Lag.	+	-	+	-	+	-
47	<i>Spirogyra fluviatilis</i> Hilse	-	+	-	+	-	+
48	<i>Spirogyra purvispora</i>	-	+	-	+	+	-
49	<i>Spirogyra weberi</i> Kutz.	-	+	++	-	-	+
50	<i>Staurastrum arachne</i> Ralfs ex Ralfs	+	-	++	-	-	-
51	<i>Staurastrum bienanum</i>	-	+	-	++	-	-
52	<i>Tetraspora gelatinosa</i>	+	+	-	-	+	-
53	<i>Ulothrix cylindricum</i> prescott	-	+	-	++	-	+
54	<i>Ulothrix subconstricta</i> Gs West	+	-	-	-	+	-
55	<i>Ulothrix zonata</i> Kuetz	-	-	-	-	+	-
56	<i>Zygenema</i> sp	+	-	+	-	+	-
	Bacillariophyceae						
57	<i>Achnanthes minutissima</i> Kutz	-	-	+	-	++	-
58	<i>Amphora</i> sp	-	+	-	+	-	++
59	<i>Calonesis undulata</i> (Greg.) Kram.	-	-	-	+	++	-
60	<i>Cyclotella glomerata</i> Bachm.	+	+	-	++	-	+
61	<i>Cymbella aspera</i> (Ehr.) Cleve	-	++	+	-	+	-
62	<i>Cymbella gracilis</i> (Ehr.) Kutz.	+	+	-	+	+	-
63	<i>Cymbella prostata</i> Cleve	-	+	-	+	-	-
64	<i>Cymbella reinhardtii</i> Grun.	+	-	-	-	-	-
65	<i>Cymbella</i> sp	-	+	+	-	+	-
66	<i>Cymbella tumescens</i> A.Cleve	+	-	+	++	-	-
67	<i>Cymbella tumida</i> (Breb.) Heurck	-	+	-	-	+	-
68	<i>Cymbella turgidula</i> Grun	++	-	+	-	+	-
69	<i>Cymbella ventricosa</i> var. <i>arcuata</i> Gurn.	-	++	-	++	-	+
70	<i>Cymbella ventricosa</i> var. <i>arcuata</i>	++	++	-	-	-	+
71	<i>Diploneis</i> sp	-	-	+	-	+	-
72	<i>Diploneis subovalis</i> Cleve	++	-	-	+	-	+
73	<i>Eunatiabilunaxis</i>	-	+	+	-	-	+
74	<i>Fragilaria brevistriata</i> Grun	++	-	+	-	++	-
75	<i>Fragilaria capucina</i> Desma.	-	+	-	+	+	+
76	<i>Fragilaria capucina</i> Desmaziers	-	-	+	-	+	-
77	<i>Fragilaria</i> sp	+	+	-	+	-	-
78	<i>Fragilaria pinnata</i> Her.	+	-	-	+	-	+
79	<i>Gomphonema clevatoides</i> Gandhi	-	+	-	+	++	-
80	<i>Gomphonema cristatum</i> Ralfs	++	-	-	-	+	+
81	<i>Navicula cryptocephala</i> Kutz.	-	++	+	+	-	-
82	<i>Navicula pupila</i>	-	-	-	+	+	++
83	<i>Navicula salinarum</i>	+	-	+	+	++	-
84	<i>Nitzschia obtusa</i> W.Smith	+	++	-	-	-	-





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85	<i>Nitzschia palea</i>	-	-	+	-	+	+
86	<i>Pinnularia acrosphaeria</i> W.Smith	+	+	-	++	-	+
87	<i>Pinnularia graciloides</i> Hust	-	-	+	+	-	-
88	<i>Pinnularia</i> sp	++	+	++	-	-	++
89	<i>Pleurosigma delicatulum</i> W. Smith	-	-	-	-	+	++
90	<i>Rhopalodia gibba</i> (Ehr) O.Mull	+	-	+	++	-	++
91	<i>Rhopalodia gibba</i> Ehr.	-	+	-	+	+	-
92	<i>Stauronesis anceps</i> Ehr.	+	-	+	-	+	++
93	<i>Synedra ulva</i>	-	+	+	+	-	-
	Cyanophyceae						
94	<i>Apano capsapulchera</i> Kutz	-	+	-	+	-	+
95	<i>Aphanothece stagnina</i> (Spr.) A.Braun	-	-	-	+	-	+
96	<i>Aulosira</i> sp	+	-	+	-	++	-
97	<i>Chroococcus cohaerens</i> (Breb.) Nag.	-	+	-	++	-	++
98	<i>Dactylococcopsis</i> sp	-	+	-	+	-	++
99	<i>Lyngbya digueligom</i>	+	-	+	-	+	-
100	<i>Microcystis aeruginosa</i> Kutz.	-	-	+	+	-	+
101	<i>Microcystis bengalensis</i> Banerji	+	-	-	+	-	+
102	<i>Microcystis incerta</i> Lemm.	+	-	+	-	+	+
103	<i>Microcystis viridis</i> Lemm	-	+	-	+	-	-
104	<i>Microcystis aeruginosa</i>	-	-	++	-	+	-
105	<i>Microcystis flos-aquea</i>	+	-	-	+	-	-
106	<i>Oscillatoria amphi granulata</i> Goor.	-	++	-	+	-	-
107	<i>Oscillatoria curvicepsc.</i> Agarth ex Goment	+	-	+	-	++	-
108	<i>Oscillatoria limosac.</i> Agarth ex Goment	-	+	-	+	-	++
109	<i>Oscillatoria nigra</i> Vaucher	+	-	+	-	-	-
110	<i>Oscillatoria obtua</i> Gardner	-	+	-	+	-	+
111	<i>Oscillatoria princeps</i> voucher ex Goment	+	-	+	-	++	-
112	<i>Oscillatoria rubescens</i> De Candolle	++	-	++	-	+	+
113	<i>Oscillatoria sancta</i> (Kutz.) Gomont	-	+	-	+	-	+
114	<i>Oscillatoria</i> sp	+	-	+	-	-	+
115	<i>Oscillatoria subbrevis</i> Sch.	+	+	-	-	++	-
116	<i>Oscillatoria subbrevis</i> Schmidle	-	-	+	-	-	+
117	<i>Oscillatoria willei</i> Gardner	++	+	-	-	+	-
118	<i>Phormidium</i>	+	+	-	++	-	++
119	<i>Scytonema</i> sp	-	-	+	-	++	-
120	<i>Synechocystis aquatilis</i>	+	-	-	++	-	++
121	<i>Tolypothrix distorta</i>	-	+	-	-	+	-
	Euglenophyceae						
122	<i>Euglena polymorpha</i>	-	+	+	-	+	-
123	<i>Phacus acuminatus</i> Stokes	+	-	+	+	-	+
124	<i>Phacus agilis</i> skuja	+	++	-	+	+	+
125	<i>Trahemonas</i> sp	-	-	+	-	+	-

+++ = Abundant; ++ = Dominant; + = Rare; - = Absent





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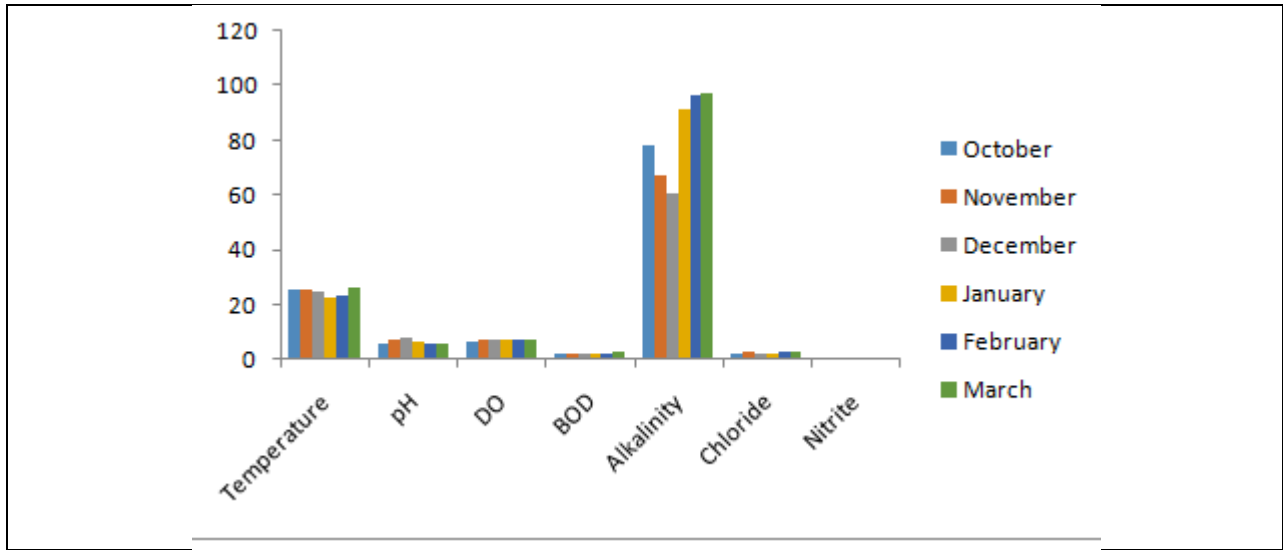


Figure: 1: Physico-chemical parameters





The Effect of Sport on Life Skills in High School Students

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ABSTRACT

Participation in athletic activities as a means for high school pupils to acquire valuable life skills is the focus of this research. Participating in the research were 96 athlete-students, ranging in age from 14 to 18 years old, with 49 men and 47 females representing different educational levels. After collecting data using a questionnaire, the quantitative data was analyzed using statistical tools such as Pearson Correlation Analysis, One-Way ANOVA, and independent groups t-tests. Participation in athletic activities is associated with high rates of life skill learning among high school students, according to the results. Participation in athletic activities has a beneficial effect on the development of several transferable qualities, such as resilience, leadership, communication, and problem-solving abilities. Additionally, there were gender and educational level disparities in the correlation between athletic involvement and the development of life skills. The research shows that high school athletic activities help pupils grow in all areas of their lives. It implies that playing sports improves health in more ways than one and helps hone important life skills that are important for success in many areas. The results highlight the need of maintaining funding and support for sports programs in schools, which has consequences for youth development practitioners, lawmakers, and educators.

Keywords: Sports, high school students, life skills, development, athletes, gender differences, educational levels, quantitative analysis, teamwork, leadership, communication, problem-solving, resilience, youth development.

INTRODUCTION

The complex impact of high school students' involvement in extracurricular activities, especially athletics, on their personal and academic growth is becoming more acknowledged in modern discussions of education. Policymakers



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and educators alike are placing a greater emphasis on the need of developing transferable abilities that will help students succeed in a wide range of contexts outside the classroom. In this introductory section, we lay the groundwork for investigating how high school athletics affect the development of these transferable abilities, paying special attention to any disparities that may exist according to gender and degree of schooling. There are major changes occurring in one's brain, social life, emotions, and physical health throughout the transition from childhood to adulthood. A person's identity, goals, and future paths are shaped during this time by the possibilities and threats they face. The development of life skills, which are the tools one needs to deal with the inevitable ups and downs of daily living, is at the heart of this path of personal growth. The ability to work with others, solve problems, control one's emotions, and bounce back from setbacks are all part of this set of talents. Participation in athletic activities has long been acknowledged as a potent medium for promoting the all-around development of youth. Participating in sports provides a one-of-a-kind setting for learning and self-improvement, in addition to the obvious physical advantages. Athletics provides players with several opportunities to learn and hone important life skills via disciplined training, competition, and collaboration. For example, playing on a team helps develop important social skills like listening, working together, and resolving conflicts. In addition, sports endeavors provide chances to hone resilience, persistence, and goal-setting skills via their inherent hurdles. Although there is consensus on the potential advantages of childhood sports engagement for development, there is a lack of research that specifically examines how high school students acquire life skills. Previous research has mostly focused on examining the correlation between athletic participation and outcomes including health, social adjustment, and academic performance. But we don't really know how sports help build the kinds of life skills that are important for getting through adolescence and beyond. To fill this knowledge vacuum, the present research will analyze high school athletics through the lens of its potential to foster all-around growth in its participants.

A quantitative research strategy will be used to accomplish these goals. Throughout the 2018-2019 school year, 219 student athletes (141 men and 78 females) will take part in the research. Their ages range from 11 to 24, and they come from a variety of educational backgrounds. The questioneer, a proven tool for gauging participation in sports and the acquisition of valuable life skills, will be used to gather data. In order to assess the numerical data, statistical tests will be run, such as Pearson's correlation analysis, one-way analysis of variance, and independent groups t-tests. Educational policy, practice, and research may all benefit greatly from this study's findings. It sheds light on the connection between high school athletes' involvement in athletics and the development of life skills, which is useful for practitioners, politicians, and educators working on youth development programs. Results may guide efforts to improve high school students' health, wellness, and holistic development via athletic activities. A more sophisticated comprehension of the intricate relationship between participation in sports and the development of life skills is enhanced by the study's emphasis on possible gender and educational level disparities.

The Importance of Athletics for Students

Just as a balanced diet is essential for maintaining good health, regular physical activity, particularly for developing youngsters, greatly improves our quality of life. Playing sports helps students deal with the stress of exams and gets them mentally and physically ready for future difficulties, which is only one of the numerous obstacles that students encounter. Young people who regularly participate in physical activities are more likely to develop the virtues of kindness, generosity, and teamwork. Participating in athletic activities helps kids develop important life skills like taking charge, collaborating effectively, and believing in themselves.

Sports help in maintaining Good Health

In this day and age of cutthroat competitiveness and ever-evolving environmental conditions, few individuals give a hoot about our health, and we all pay the price as we become old. They are prone to a wide range of potentially fatal health problems. Those who engage in regular physical exercise are better able to stave against these illnesses. Hence, engaging in athletic activities helps alleviate this worry. Maintaining a healthy blood sugar level, enhancing cardiac function, and decreasing stress and anxiety are all benefits of frequent athletic participation.



**Mruigesh Singh Shekhawat and Sathish Kumar****The Influence of Athletics on Character**

You learn a lot about yourself and how to live your life better via athletics. Participating in such pursuits equips you with lifelong lessons in morality, ethics, and competence. A more optimistic view on life and the ability to overcome challenges become hallmarks of this state. Not only that, but it also helps individuals deal with stress by encouraging them to see obstacles in a positive light. They become more efficient, which gives them the confidence to take on problems. Participating in athletic activities may help people develop many valuable life skills. Competing in every sport helps us to think on our feet, make snap judgments, and solve problems. Learning to live, manage one's life, and take the lead are all skills honed via athletic competition. So, playing sports is about more than simply having fun; it's also about gaining valuable life lessons.

Learning from Sports

Athletics teach self-control. Proper seating, speaking, walking, etc., are all taught in it. Sports keep the body active, fit, and trim, and they stimulate all the cells in the body, so living without them feels too dull. Playing sports is a great way to relieve mental tension and improve your cognitive skills. People who don't care much for sports are less likely to exercise, which increases their risk of developing certain diseases at a younger age and makes them sluggish at work. So that students learn the value of physical activity from a young age, sports should be required in schools. Cricket is a popular sport in India, where many people enjoy watching and participating in the sport. Despite the influx of new players, fans of Kapil Dev, Sachin Tendulkar, M.S. Dhoni, and Virat Kohli will always root for these legends. Many individuals who have an interest in football look up to football stars like Ronaldo, Messi, and many more. As a whole, people generally agree that athletic events, like the Olympic Games, form the basis of sports. There are certain standards that all sports must adhere to in order to ensure fair competition. These rules state that the games must not injure any participants and that the best or better athletes should be chosen as winners. Mind and reasoning ability are enhanced in activities such as chess. The question of whether or not transgender people should be permitted to compete in athletic competitions has become more contentious since the turn of the century.

Benefit of Technology in Sports

Modern sports also rely heavily on technology to determine victors based on fair play. Viewing a racing car driver accurately on a screen is helpful for judging their performance, and the same is true in cricket, where technology is used when a choice becomes very challenging. It has been used to declare the victors and ensure fair play in every sport. The potential for sports to foster good development and link young people with optimistic thinking has been well-documented. Having a college degree isn't required of athletes, but it helps them perform at their best. His passion, strength, and abilities are all in one area. Over the last 20 years, we've witnessed a rise in female athletes, and the government has even gone to great lengths to ensure that they have access to appropriate matches. Participating in athletic activities cultivates an optimistic outlook on life. There are many different types of sports, some played indoors (such as chess or carrom board) and others played outdoors (such as football, cricket, rugby, kabaddi, etc.), so it stands to reason that those who play more outdoor sports will be in better physical shape. Not nearly as much interest in athletic opportunities existed thirty to forty years ago as there is among today's children. Athletics provide stability and a way of life. Hockey, which originated in India and is now our national sport, is one of the top ten most popular sports in the world, with soccer, cricket, basketball, tennis, volleyball, table tennis, and baseball. Kabaddi, polo, archery, weightlifting, and a few more sports also get little attention. Everyone knows that swimming is the safest sport. Sports are great for our health and mobility, thus everyone should play them. According to the research, sports help keep a lot of health problems in check, including obesity, heart disease, lung function, and cognitive abilities. Players in ice hockey and soccer earn the most money. Another thing is that certain sports call for huge arenas while others may be played in more intimate settings. Playing sports keeps us moving and energizing, and some medical professionals even recommend them as a means of sickness recovery. Regular physical activity, including sports, should not be optional but rather mandated for all individuals.

OBJECTIVES OF THE STUDY

1. Participation in athletic activities as a means by which high school kids gain valuable life skills is the major focus of this research. The specific goals of the research are as follows: to learn how participating in sports



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- affects the acquisition of important soft skills including leadership, communication, problem-solving, resilience, and collaboration.
2. Research on the correlation between athletic involvement and the acquisition of transferable abilities should take into account any possible gender variations.
 3. Investigate whether the correlation between athletic participation and the development of transferable abilities varies according to students' levels of education.

REVIEW OF LITERATURE

Physical education (PE) programs in schools have been recognized for a long time as being crucial components of an education that really encompasses all aspects of life. Physical education is increasingly recognized for its capacity to enhance the complete development of students, especially in terms of personality development and interpersonal skills. This is in addition to the fact that it promotes physical health and fitness. According to research, the controlled setting of physical education courses, in conjunction with the chances for students to participate in a variety of sports and activities, serves to offer students with useful experiences that contribute to their personal development [1]. Furthermore, academics underline that the quality of the experiences and relationships that occur within the context of sports activities is a crucial factor that contributes considerably to good development outcomes. This is in contrast to the more common practice of just participating in sports activities. The character and conduct of people are significantly influenced by a variety of events, including but not limited to difficulties, successes, failures, dynamics of collaboration, and possibilities for leadership [2]. As part of the process of aligning with larger educational goals, schools are urged to establish goals that not only prepare kids for academic achievement but also for success in a variety of other facets of life. Encouragement of the development of social and emotional skills is included in this. These abilities are necessary for the formation of meaningful relationships, the management of stress, and the successful navigation of a variety of social situations [3]. Schools are able to better equip students with the tools they need to flourish in both academic and non-academic environments if they include the development of life skills into their curriculum. Life skills, which may be described as a collection of qualities that help individuals to successfully handle the obstacles and demands of daily life, have emerged as a primary emphasis area in the efforts that are being made to develop young people. These abilities comprise a broad variety of characteristics, such as communication, problem-solving, decision-making, critical thinking, empathy, and resilience, among others. Recognizing the significance of life skills in preparing young people for adulthood, researchers and educators alike have stressed the need of incorporating the development of life skills into a variety of educational settings, including physical education programs [4]. In recent years, there has been a rising interest in investigating the potential of sports involvement as a vehicle for fostering good youth development, with a special focus on the acquisition of life skills.

This interest will continue to expand. Sports participation has been found to be associated with the development of a wide variety of life skills, including but not limited to leadership, collaboration, communication, goal-setting, time management, and emotional control [5]. Studies have repeatedly shown that participation in sports activities may contribute to the development of these life skills. Furthermore, academics have started to construct frameworks and measuring techniques in order to evaluate the efficacy of sports programs in terms of aiding the development of life skills. As an example, the Life Skills Scale for Sport (LSSS) offers a complete measurement of the life skills that are expected to be gained by involvement in sports. Using this scale, researchers are able to conduct a systematic evaluation of the influence that sports programs have on the acquisition and improvement of certain life skills among participants [6]. In spite of the expanding amount of data that supports the favorable association between involvement in athletics and the development of life skills, there is still a need for more study to better understand the processes that underlie this relationship. Furthermore, in order to guarantee efficacy and long-term viability, it is essential that attempts to foster the development of life skills via athletics be followed by careful program design, training for coaches and instructors, and continual assessment [7]. [18] A total of 546 elementary school students from Canada took part in a research that was quasi-experimental in nature. The purpose of the study was to explore the effects of providing an extra hour of intense physical education each day to students who were being instructed by a



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trained teacher. The control groups consisted of students from classes that were directly above and below the experimental group. These students were exposed to forty minutes of physical education on a weekly basis from their academic instructor. Even though the experimental group received 14% less academic training than the control group, the experimental group's academic performance considerably improved in comparison to the control group. During the first few months of the intervention, the experimental group of students had a rapid improvement in a variety of psychomotor abilities, including perception. However, the control group of students caught up to the experimental group later on in the research.

RESEARCH METHODOLOGY

In this study, we have adapted a qualitative research approach using a stratified sampling and we have chosen 96 sampling units. In this quantitative investigation, an online questionnaire will serve as the primary tool for data collection. The utilization of an online questionnaire offers numerous advantages, including accessibility, convenience for respondents, and the ability to reach a diverse and expansive sample of individuals. This methodology aligns with the objectives of the study, which aims to examine the relationship between sports participation and the development of life skills among high school athletes.

Data Collection

Students from all walks of life and all levels of education will participate in the online survey for high school athletes. Schools, sporting groups, and internet platforms will all play a role in participant recruitment. Questions on how often people participate, what kinds of sports they play, how long they play for, and what they think are the advantages of playing sports will all be part of the survey. In addition, we will inquire about the participants' age, gender, and level of education.

DEMOGRAPHIC ANALYSIS

Table 1 presents the age distribution of athletes participating in the study. The majority of athletes are aged 16 (32.3%) and 17 (30.2%), followed by those aged 15 (19.8%) and 18 (17.7%). The table shows that the sample is fairly evenly distributed across the different age groups, with a total of 96 athletes included. This distribution provides a representative sample for examining the relationship between age and other variables in the study. Table 2 displays the gender distribution among athletes in the study. Of the total sample of 96 athletes, 51.0% are male, while 49.0% are female. This indicates a relatively balanced representation of genders within the sample. The table highlights the importance of considering gender as a demographic factor in the analysis of sports participation and life skills development, as it may influence various aspects of athletic experience and outcomes.

ANALYSIS AND FINDINGS**CORRELATIONS ANALYSIS**

The correlation between sports frequency and years involved is significant at a 0.01 level (2-tailed), showing a strong negative relationship of approximately -0.475 . This suggests that as sports frequency increases, the number of years involved decreases, and vice versa. In other words, individuals who participate more frequently in sports tend to have been involved in them for fewer years, while those with more years of involvement tend to participate less frequently. The correlation between holding a leadership role and teamwork ability is highly significant at the 0.01 level (2-tailed), with a strong positive correlation of approximately 0.537 . This indicates that individuals who excel in leadership roles also tend to demonstrate strong teamwork abilities, and vice versa. It suggests a complementary relationship between leadership skills and the ability to work effectively within a team, highlighting the importance of both qualities in organizational settings. The correlation between well-being impact and life skills impact is extremely significant at the 0.01 level (2-tailed), with a remarkably strong positive correlation of approximately 0.862 . This implies that individuals who experience a positive impact on their well-being also tend to see a significant



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enhancement in their life skills, and vice versa. It underscores the interconnectedness between well-being and the development of essential life skills, suggesting that improvements in one domain can positively influence the other. ANOVA results for the Leadership Role indicate that there is no significant difference between groups ($F(1, 94) = 0.100, p = 0.753$). The between-groups sum of squares is 0.024, within-groups sum of squares is 22.476, and total sum of squares is 22.500. This suggests that the variability between groups is not statistically meaningful, implying that the presence or absence of a leadership role does not have a significant impact on the measured variable. For the Life Skill Impact, the ANOVA results indicate a highly significant difference between groups ($F(2, 93) = 137.073, p < 0.001$). The between-groups sum of squares is 25.567, within-groups sum of squares is 8.673, and the total sum of squares is 34.240. This suggests that there are significant differences in life skill impact across the groups being compared, implying that the factor being studied has a substantial effect on life skill development. For Teamwork Ability, the ANOVA results reveal a highly significant difference between groups ($F(2, 93) = 54.796, p < 0.001$). The between-groups sum of squares is 28.124, within-groups sum of squares is 23.866, and the total sum of squares is 51.990. This suggests that there are notable differences in teamwork ability across the groups being compared, indicating that the factor under study has a considerable impact on teamwork skills.

T TEST

The Levene's test indicates unequal variances for Life Skills Impact, leading to both equal and unequal variance t-tests. Both tests reveal a significant difference ($p = 0.002$ and $p = 0.004$, respectively) between groups. The mean difference of approximately 0.003 suggests that one group has a significantly lower impact on life skills compared to the other. This underscores the importance of considering variances in group comparisons, as it can affect the interpretation of results and choice of statistical tests. The Levene's test indicates equal variances for Problem-Solving Impact, allowing for both equal and unequal variance t-tests. Both tests show no significant difference ($p = 0.374$ and $p = 0.749$, respectively) between groups. The mean difference of approximately 0.749 suggests no substantial variation in problem-solving impact between the compared groups. This implies that, regardless of the assumption about variances, there's no statistically significant distinction in problem-solving impact observed between the groups.

FINDINGS

The study explores the relationship between high school students' participation in sports and the development of life skills, with a focus on gender and educational level differences. Quantitative data collected from 96 athlete-students, ranging from 14 to 18 years old, were analyzed using statistical methods including correlation analysis, ANOVA, and independent samples t-tests. The correlation analysis revealed significant relationships between sports frequency and years involved, leadership role and teamwork ability, as well as well-being impact and life skills impact. These findings suggest that increased sports frequency correlates with fewer years involved, indicating a dynamic where individuals either intensify their involvement in sports over fewer years or sustain long-term involvement with lower frequency. Furthermore, there's a strong positive correlation between holding leadership roles and demonstrating teamwork abilities, emphasizing the complementary nature of these skills. Additionally, the study highlights a remarkably strong positive correlation between well-being impact and life skills impact, indicating that improvements in well-being are associated with enhanced life skills development. ANOVA results showed significant differences in life skill impact and teamwork ability across different groups, implying that factors such as participation in sports or other interventions have a substantial influence on life skill development among high school students. However, the ANOVA for leadership role did not yield significant differences between groups, suggesting that the presence or absence of a leadership role may not significantly impact the measured variable. The independent samples t-tests further elucidated the findings. Unequal variances were observed for life skills impact, leading to significant differences between groups. This underscores the importance of considering variances in group comparisons. On the other hand, equal variances were observed for problem-solving impact, with no significant differences found between groups, regardless of the assumption about variances. This suggests that there's no statistically significant distinction in problem-solving impact between the compared groups. Overall, the study contributes to the understanding of how participation in sports influences the acquisition of life skills among high



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school students. It emphasizes the importance of sports programs in schools for promoting holistic development, including the cultivation of leadership, teamwork, communication, problem-solving, and resilience skills. Additionally, the study highlights the need to consider gender and educational level disparities in the correlation between sports involvement and life skills development, providing valuable insights for educators, policymakers, and youth development practitioners.

CONCLUSIONS

In conclusion, this study underscores the significant impact of sports participation on the development of life skills among high school students. The findings highlight the positive correlations between sports engagement and various life skills such as leadership, teamwork, communication, problem-solving, and resilience. Notably, the study reveals that increased sports frequency is associated with enhanced life skills, suggesting that regular participation in athletic activities fosters multifaceted personal growth. Furthermore, the results emphasize the interconnectedness between well-being and life skills development, indicating that improvements in well-being positively influence the acquisition of essential life skills. These findings underscore the holistic benefits of sports participation, beyond physical health, in nurturing students' social, emotional, and cognitive competencies. The study also sheds light on gender and educational level differences in the correlation between sports involvement and life skills development. Understanding these disparities is crucial for tailoring sports programs to meet the diverse needs of students and ensuring equitable opportunities for skill development. Moreover, the significant differences observed in life skill impact and teamwork ability across different groups highlight the importance of continued support for sports programs in schools. Such programs play a vital role in promoting holistic development and preparing students for success in various aspects of life.

REFERENCES

1. S. Danish, T. Forneris, K. Hodge, and I. Heke, "Enhancing youth development through sport," *World Leis. J.*, vol. 46, no. 3, pp. 38–49, 2004, DOI: 10.1080/04419057.2004.9674365.
2. S. J. Danish, T. Forneris, and I. Wallace, "Sport- based life skills programming in the schools," *J. Appl. Sch. Psychol.*, vol. 21, no. 2, pp. 41–62, 2005, DOI: 10.1300/J370v21n02_04.
3. R. Bailey, "Sport, physical education and educational worth," *Educ. Rev.*, vol. 70, no. 1, pp. 51–66, 2018, DOI: 10.1080/00131911.2018.1403208.
4. C. Bean and T. Forneris, "Examining the Importance of Intentionally Structuring the Youth Sport Context to Facilitate Positive Youth Development," vol. 3200, no. June, pp. 0–16, 2016, DOI: 10.1080/10413200.2016.1164764.
5. T. Forneris, M. Camiré, and P. Trudel, "International Journal of Sport and The development of life skills and values in high school sport : Is there a gap between stakeholder ' s expectations and perceived experiences ?" no. October 2014, pp. 37–41, DOI: 10.1080/1612197X.2012.645128.
6. D. Gould and S. Carson, "Life skills development through sport: current status and future directions," *Int. Rev. Sports Exerc. Psychol.*, 2008, DOI: 10.1080/17509840701834573.
7. L. D. Cronin and J. Allen, "Development and initial validation of the Life Skills Scale for Sport," *Psychol. Sports Exerc.*, vol. 28, pp. 105– 119, 2017, DOI: 10.1016/j.psychsport.2016.11.001.
8. R. Rohmanasari, A. Ma'mun, and T. Muhtar, "DampakKegiatanEkstrakurikulerterhadapPerkembangan," *J. Penelit. Pendidik.*, vol. 18, no. 3, pp. 371–382, 2018.
9. C. Trottier and S. Robitaille, "Fostering Life Skills Development in High School and Community Sport : A Comparative Analysis of the Coach ' s Role," no. 2000, pp. 10–21, 2014.
10. M. A. Whitley, E. M. Wright, and D. Gould, "Journal of Sport for Development Coaches 'erspectives on Sport-Plus Programmes for Underserved Youth : An Exploratory Study in South Africa," vol. 1, no. 2, 2013.





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11. K. Kendall, M. Camiré, C. N. Bean, and T. Forneris, "Integrating life skills into Golf Canada 's youth programs : Insights into a successful research to practice partnership," vol. 0704, no. September 2016, DOI: 10.1080/21520704.2016.1205699.
12. J. R. Fraenkel, N. E. Wallen, and H. H. Hyun, How to Design and Evaluate Research in Education T, Eighth Edi. New York, Americas: The McGraw- Hill Companies, 2012.
13. L. Cronin et al., "Life skills development in physical education: A self-determination theory- based investigation across the school term," Psychol. Sports Exerc., vol. 49, no. May, p. 101711, 2020, doi: 10.1016/j.psychsport.2020.101711.
14. R. W. Larson, D. M. Hansen, and G. Moneta, "Differing profiles of developmental experiences across types of organized youth activities," Dev. Psychol., vol. 42, no. 5, pp. 849–863, 2006, DOI: 10.1037/0012-1649.42.5.849.
15. D. M. Hansen, R. W. Larson, and J. B. Dworkin, "What adolescents learn in organized youth activities," J. Res. Adolesc., vol. 13, no. 1, pp. 25– 55, 2003.
16. D. Gould and S. Carson, "The relationship between perceived coaching behaviors and developmental benefits of high school sports participation," Hellenic Journal of Psychology. 2010.
17. A. Ma'am, "Development of the Educational Sport in Indonesia : The Policy Study Based on the Law of National Sports System," vol. 5, no. 1, pp. 33– 48, 2015.
18. Shephard RJ. Curricular physical activity and academic performance. Pediatric Exercise Science 1997;9:113-126.

Table 1: Frequency distribution of Age

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	15	19	19.8	19.8	19.8
	16	31	32.3	32.3	52.1
	17	29	30.2	30.2	82.3
	18	17	17.7	17.7	100.0
	Total	96	100.0	100.0	

Table 2: Frequency distribution of Gender

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	male	49	51.0	51.0	51.0
	female	47	49.0	49.0	100.0
	Total	96	100.0	100.0	

Table 3: Correlations

		Sports Frequency	Years Involved
Sports Frequency	Pearson Correlation	1	-.475**
	Sig. (2-tailed)		<.001
	N	96	96
Years Involved	Pearson Correlation	-.475**	1
	Sig. (2-tailed)	<.001	
	N	96	96

** . Correlation is significant at the 0.01 level (2-tailed).





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Table 4: Correlations

		Leadership Role	Teamwork Ability
Leadership Role	Pearson Correlation	1	.537**
	Sig. (2-tailed)		<.001
	N	96	96
Teamwork Ability	Pearson Correlation	.537**	1
	Sig. (2-tailed)	<.001	
	N	96	96

** . Correlation is significant at the 0.01 level (2-tailed).

Table 5: Correlations

		Well-being Impact	Life Skills Impact
Well-being Impact	Pearson Correlation	1	.862**
	Sig. (2-tailed)		<.001
	N	96	96
Life Skills Impact	Pearson Correlation	.862**	1
	Sig. (2-tailed)	<.001	
	N	96	96

** . Correlation is significant at the 0.01 level (2-tailed).

Table 6: ANOVA - Leadership role

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.024	1	.024	.100	.753
Within Groups	22.476	94	.239		
Total	22.500	95			

Table 7: ANOVA - Life skill impact

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	25.567	2	12.783	137.073	<.001
Within Groups	8.673	93	.093		
Total	34.240	95			

Table 8: Teamwork ability

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	28.124	2	14.062	54.796	<.001
Within Groups	23.866	93	.257		
Total	51.990	95			

Table 9: Independent Samples Test

	Levene's Test for Equality of Variances	t-test for Equality of Means							
		F	Sig.	t	df	Significance	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference





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					One-Sided p	Two-Sided p			Lower	Upper	
Life Skills Impact	Equal variances assumed	23.943	<.001	-3.010	.94	.002	.003	-.354	.118	-.588	-.121
	Equal variances not assumed		-3.010	73.283	.002	.004	-.354	.118	-.589	-.120	

Table 10: Independent Samples Test

	Levene's Test for Equality of Variances	t-test for Equality of Means									
		F	Sig.	t	df	Significance		Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						One-Sided p	Two-Sided p			Lower	Upper
Problem-Solving Impact	Equal variances assumed	5.581	.020	-.321	94	.374	.749	-.042	.130	-.299	.216
	Equal variances not assumed			-.321	82.840	.374	.749	-.042	.130	-.300	.216





A Cup of Green Tea Twice a Day is SARS-CoV-2 Preventive

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ABSTRACT

To predict the prophylaxis herbally against Covid-19, the study has discussed the composition of green tea and their functions on SARS-CoV-2 virus. Eight antiviral compounds - epigallocatechin-3-gallate, epigallocatechin, epicatechingallate, epicatechin, galocatechin-3-gallate, galocatechin, catechin gallate and catechin found in tea leaves (*Camellia sinensis*) can deactivate the main protease enzyme in SARS-CoV-2 virus and thus prevent the viral reproduction. Epigallocatechin-3-gallate, epicatechin gallate and galocatechin-3-gallate are more potent Mpro inhibitors. Synergistic effect of green tea as per a cup twice a day can prevent corona-19 disease.

Keywords: SARS-CoV-2, Covid-19, green tea, main protease inhibitor, dose

INTRODUCTION

SARS-CoV-2 pandemic can be prevented by taking green tea (*Camellia sinensis*). Higher per capita green tea consumption lowers covid-19 morbidity and mortality^[1]. Green tea contains eight antiviral compounds : epigallocatechin-3-gallate (EGCG_{MW} : 458.37), epigallocatechin (EGC_{MW} : 306.27), epicatechingallate (ECG_{MW}-442.37), epicatechin (EC_{MW}-290.27), galocatechin-3-gallate (GCG_{MW}-458.37), galocatechin (GC_{MW}-306.27), catechingallate (CG_{(MW}-442.37)) and catechin (C_{MW}-290.27) that can resist the viral infection by inhibiting Mpro enzyme^[2,3](Table -1^[4,5]). Out of which, EGCG, ECG and GCG are more potent Mpro inhibitors (Figure 1, 2 and 3^[3]).





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EGCG inhibits 85% of the viral main protease- 3CLProactivities at 200 μ M concentration^[6]. The polyphenol has a potent binding affinity with viral proteins -6lu7, 6lvn, 6lxt and 6vsb [7] and thus inhibits binding with epithelial cells of respiratory system. It also inhibits the ATPase activity of GRP78 receptor protein of host cell and thus interfere virus-GRP78 protein complex formation^[8,9] and eliminates the possibility of infection. Ester derivatives of EGCG formed due to oxidation in oral administration to reach the target, neutralize reactive oxygen species (ROS) produced in phagocytosis, inflammation and lipid oxidation and reduce the oxidative stress of our body efficiently. EGCG palmitate and EGCG stearate are more potent antiviral compounds than EGCG^[10]. Administration of EGCG with antiviral drugs increases its bioavailability and effectiveness. Methylation, acylation, esterification or glycosylation of EGCG can improve its pharmacokinetics and pharmacodynamics properties^[11].

Recently, a new polyphenol - Oolonghomobisflavan-A (MW: 928.8) extracted from green tea acts as a strong inhibitor of the viral Mpro^[12]. All the polyphenols are non-carcinogenic and non-hepatotoxic^[3] and especially EGCG, ECG, GCG and Oolonghomobisflavan-A may be considered as good drug candidates for the treatment of nCoV disease.

EGCG is the major catechin in green tea (50 – 80%) and its quantity varies from 200-300 mg /brewed cup of green tea^[13]. It is effective in human body at the concentration range of 1 – 100 μ M/Lin serum ^[14]. The bioavailability of the compound is 1.68% of oral administration^[15]. So, the efficacious oral dose is \geq 75 mg/body/day that is equivalent to a cup of brewed green tea (100ml). The tea catechins are stable for 48 hours in serum^[16]. Therefore, taking two cups of green tea a day at 12 hours of interval is enough to maintain the effective serum level.

A very low concentration of caffeine in green tea (9.6 – 16mg/cup (\approx 100ml)) is not viable to suppress T-cell proliferation and antibody production^[17], but it makes our body energetic ^[18].

Mg content in brewed green tea (1mg/100 ml) acts as cofactor for immunoglobulin synthesis^[19]. The concentration of Mn (0.18mg/100 ml) stimulates type I IFNs synthesis^[20] and increases antiviral immunity. The quantity of vit. B complex per 100 ml (B1- 0.007 mg, B2- 0.06mg, B3 – 0.03 mg and B6 – 0.005 mg) augments nutritional immunity. The virus can't survive at 40°C on any surface after 2 days ^[21]. So, the temperature of brewed green tea (>50°C) reduces the survivability of the virus in mouth, pharynx and nasal passage. The vapour emerging from hot tea warms our eyes and nasal passage and reduces the possibility of viral infection in eyes and nose.

So, brewed green tea is strongly antiviral, antioxidative, immune booster and energetic. The synergistic effect of green tea defends the SARS-CoV-2 disease perfectly. A cup of brewed green tea twice a day can be an effective dose.

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REFERENCES

1. Storozhuk M, Lee S, Lee J I, Park J. Green Tea Consumption and the COVID-19 Omicron Pandemic Era: Pharmacology and Epidemiology. *Life (Basel)* 2023; 13(3): 852. doi: 10.3390/life13030852
2. Ai Z, Liu S, Qu F, Zhang H, Chen Y, Ni D. Effect of Stereochemical configuration on the transport and metabolism of catechins from green tea across Caco-2 monolayers. *Mol* 2019; 24(6): 1185. <https://doi.org/10.3390/molecules24061185>
3. Ghosh R, Chakraborty A, Biswas A, Chowdhuri S. Evaluation of green tea polyphenols as novel corona virus (SARS CoV-2) main protease (Mpro) inhibitors – an *in silico* docking and molecular dynamics simulation study. *J Biomol Struct Dyn* 2020; 39(12): 4362-4374. doi: 10.1080/07391102.2020.1779818
4. Cataldo F. Green synthesis of silver nanoparticles by the action of black or green tea infusions on silver ions. *Eur Chem Bull* 2014; 3(3) : 280 – 289





Rana et al.,

5. Bawa SH, Harton A, Myszkowska-Ryciak, Gajewsk D, Webb M. The role of selected bioactive compounds in tea, spices, cocoa and coffee in body weight control. *Pol J ApplSci*2015; 1: 56 – 66
6. Thi T H N, Woo H-J, Kang H-K, Nguyen V, Kim Y-M, Kim D-W, Ahn S-A, Xia Y, Kim D. Flavonoid-mediated inhibition of SARS coronavirus 3C-like protease expressed in *Pichiapastoris*. *BiotechnolLett* 2012; 34 (5): 831–838. doi: 10.1007/s10529-011-0845-8
7. Khan M F, Khan M A, Khan Z A, AhamadT, Ansari W A. Identification of Dietary Molecules as Therapeutic Agents to Combat COVID-19 Using Molecular Docking Studies. *Res Sq*2020. doi: 10.21203/rs.3.rs-19560/v1
8. Ibrahim IM, Abdelmalek DH, Elfiky A A. GRP78: a cell's response to stress. *Life Sci* 2019; 226 : 156 –163. doi: 10.1016/j.lfs.2019.04.022
9. Mhatre S, Srivastava T, Naik S and Patravale V. Antiviral activity of green tea and black tea polyphenols in prophylaxis and treatment of COVID-19: A review. *Phytomedicine* 2021; 85 : 153286. doi: 10.1016/j.phymed.2020.153286
10. Hsu S. Compounds Derived from Epigallocatechin-3-Gallate (EGCG) as a Novel Approach to the Prevention of Viral Infections. *Inflamm Allergy - Drug Targets (Formerly Curr. Drug Targets - Inflamm. Allergy)*2015;14(1):13–18. doi: 10.2174/1871528114666151022150122
11. Xu J, Xu Z, Zheng W. A review of the antiviral role of green tea catechins. *Mol* 2017; 22(8) : 1337. doi: 10.3390/molecules22081337
12. Bhardwaj V K, Singh R, Sharma J, Rajendran V, Purohit R, Kumar S. Identification of bioactive molecules from tea plant as SARS-CoV-2 main protease inhibitors. *J Biol Struct Dyn*2020;39: 3449-3458. doi:10.1080/07391102.2020.1766572
13. Khan N, Afaq F, Saleem M, Ahmad N, Mukhtar H. Targeting multiple signaling pathways by green tea polyphenol (-)-epigallocatechin-3-gallate. *Cancer Res* 2006; 66 (5):2500–5. doi: 10.1158/0008-5472.CAN-05-3636
14. Cai Z-Y, Li X-M, Liang J-P, Xiang L-P, Wang K-R, Shi Y-L, Yang R, Shi M, Ye J-H, Lu J-L, Zheng X-Q, Liang Y-R. 2018. Bioavailability of Tea Catechins and Its Improvement. *Mol*2018; 23: 1-18. doi:10.3390/molecules23092346
15. Warden B A, Smith L S, Beecher G R, Balentine D A, Clevidence B A. Catechins are bioavailable in men and women drinking black tea throughout the day. *J Nutr*2001; 131(6) : 1731–1737. doi: 10.1093/jn/131.6.1731
16. Zinellu A, Sotgia S, Scanu B, Forteschi M, Giordo R, Cossu A, Posadino A M, Carru C, Pintus G. 2015. Human Serum Albumin Increases the Stability of Green Tea Catechins in Aqueous Physiological Conditions. *Plos One* 2015; 10(7) : e0134690. doi: 10.1371/journal.pone.0134690
17. Horrigan L A, Kelly J P, Connor T J. Immunomodulatory effects of caffeine: friend or foe? *Pharmacol Ther*2006 ;111(3) : 877-92. doi: 10.1016/j.pharmthera.2006.02.002
18. Leathwood PD, Pollet P. Diet-induced mood changes in normal populations. *J Psychiatr Res*1982-1983; 17(2) :147–154. doi: 10.1016/0022-3956(82)90016-4
19. Galland L. Magnesium and immune function: an overview. *Magnesium*1988; 7(5-6) :290-299. PMID: 3075245
20. Haase H. Innate Immune Cells Speak Manganese. *Immunity*2018; 48(4) : 616-618. <https://doi.org/10.1016/j.immuni.2018.03.031>
21. Riddell S, Goldie S, Hill A, Eagles A, Drew T W. The effect of temperature on persistence of SARS-CoV-2 on common surfaces. *Virol J*2020 ;17: 145. <https://doi.org/10.1186/s12985-020-01418-7>

Table -1: Composition of green tea[4].

Component	Quantity (in %)
Epigallocatechin-3- gallate (EGCG)	20.3 ^[4]
Epigallocatechin (EGC)	8.4 ^[4]
Epicatechingallate (ECG)	5.2 ^[4]
Epicatechin (EC)	2.0 ^[4]
Catechin (C)	30 – 42 ^[4]
Flavanols	2.2 ^[4]
Theogallin	2 – 3 ^[4]
Caffeine	7.4 ^[4]





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Theanine	4.7 ^[4]
Glutamic acid	0.5 ^[4]
Aspartic acid	0.5 ^[4]
Quinic acid	2.0 ^[4]
Arginine	0.7 ^[4]
Other amino acids	0.8 ^[4]
Methylxanthines	7 – 9 ^[4]
Sugars	6.7 ^[4]
Alcohol (insoluble)	12.2 ^[4]
K ⁺	4.0 ^[4]
Minerals	6 – 8 ^[4]
Aroma components	0.1 ^[4]

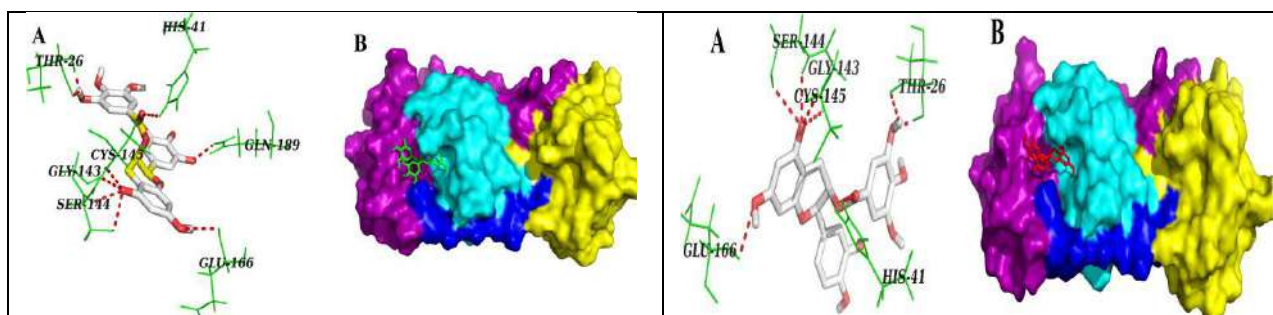


Figure 1: Stereo-view of the docked conformation of the Mpro–EGCG complex showing the possibility of hydrogen bonding interactions with the amino acid residues of Mpro (A). Surface representation shows the interaction of EGCG (green stick) at the substrate-binding region of Mpro (B). EGCG forms hydrogen bonding with many amino acid residues including His41 and Cys145 of Mpro[3].

Figure 2: The docked conformation of the Mpro–ECG complex depicts the possible hydrogen bonding interactions with various amino acids of Mpro (A). Surface representation shows the binding of ECG (red) with Mpro (B). ECG forms hydrogen bonding with many amino acid residues including His41 and Cys141 of Mpro[3].

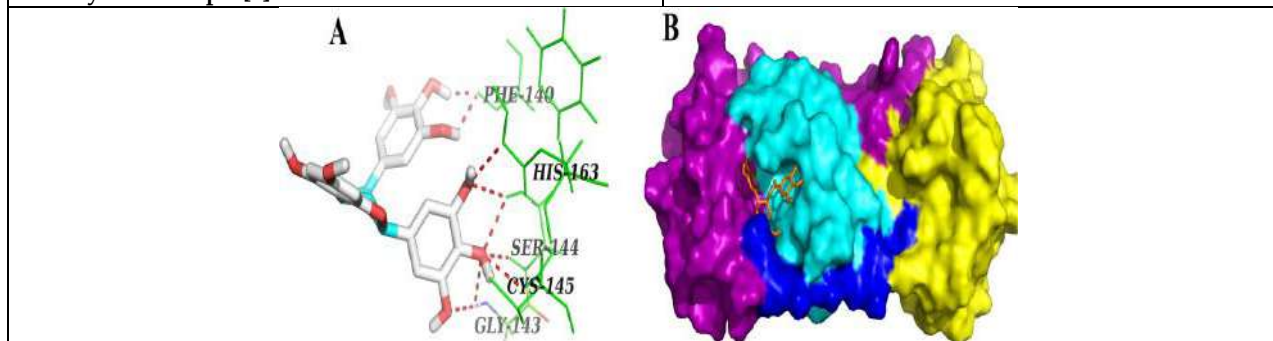


Figure 3: Molecular docking of GCG with Mpro. Various hydrogen bonds with different amino acid residues of Mpro with GCG are shown in panel A. Binding of GCG (orange) at the active site of Mpro is illustrated in panel B as surface representation. GCG interacts with nine amino acid residues including Cys145 of Mpro via H-bonds [3].





Analyzing the Traumatic Fidelity in *Kindred* by Octavia E. Butler: An Exploration on Trans-Feminine Experiences

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ABSTRACT

Octavia E. Butler (1947-2006), an African American author, gained prominence for her science fiction novels centered on futuristic societies and extraordinary abilities. Her works stand out due to their distinctive blend of science fiction, mysticism, mythology, and the spiritual beliefs of the African American community. In the realm of literature, there has been a notable intellectual exploration of the nature of womanhood, resulting in a multifaceted understanding of women and their experiences. This paved the way for women's recognition and success in various spheres. Many writers portrayed women in diverse and successful ways, but one writer who stands out is Octavia Estelle Butler, particularly in the genre of science fiction. Butler's ability to intricately delve into the psyche of women sets her apart and makes her work exceptional in this genre. This research paper focuses on Butler's novels *Kindred* (1979), which provide a prescient portrayal of female protagonists who possess distinctive somatic and psychic abilities. Furthermore, the paper attempts to study the traumatic experiences that shape the female protagonists' paths in life, examining in various aspects, includes transition from suffering to survival, her progression from seeking social recognition to achieving self-actualization, and her transformation from a feminine state to a trans-feminine state.

Keywords: African American, science fiction, trauma, self-actualization, trans-feminine experience





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INTRODUCTION

The role of women and their significance in society has been a topic of increasing attention and importance across various fields, including art and literature. Despite facing subjugation and rejection on factors such as class, race, gender, and nationality, women continue to play a crucial role in making life more complete, interesting, and inspiring. Even in the realm of literature, there has been a notable intellectual exploration of the nature of womanhood, resulting in a multifaceted understanding of women and their experiences. This exploration has paved the way for women's recognition and success in various spheres. Both male and female literary writers have portrayed women in diverse ways, but one writer who stands out is Octavia Estelle Butler, particularly in the genre of science fiction. Butler's ability to intricately delve into the psyche of women makes her work exceptional in science fiction.

Women's Empowerment and Enlightenment

The conventional narratives about women were often narrow down to portraying their subjugation and struggles. However, Octavia E. Butler deviates from this norm by presenting a rare phenomenon in her works - the exploration of women's empowerment and enlightenment. This research focuses on five of Butler's novel, *Kindred* (1979) provide a prescient portrayal of female protagonists who possess distinctive somatic and psychic abilities.

The female protagonists of Butler possessed a unique quality that make their journey towards 'empowered social recognition' and 'enlightened self-actualization' even more remarkable as well as inspiring. This paper focuses on the special attention the traumatic experiences, a psychological emotion that shape the female protagonists' journey in life, probing three key aspects:

- Transition from suffering to survival,
- Progression from seeking social recognition to achieving self-actualization, and
- Transformation from a feminine state to a trans-feminine state.

The Journey from Feminine Suffering to Transcended Femininity

In the novel *Kindred*, the female protagonist, Edana Franklin, embarks on a profound journey that transcends the realm of feminine suffering and leads to a state of transcended femininity. The concept of suffering can be interpreted in various ways, but it is commonly understood as a state of mental instability. Similarly, pain is often associated with physical injury. Both pain and suffering can profoundly impact an individual's behavior, often resulting in drastic changes that can have life or death consequences.

It is worthwhile to examine the insights provided by Daniel Jay Millman, a renowned American athlete, writer, and professor in the field of personal development, to gain a deeper understanding of Butler's female protagonists. Millman in one of his notable works, *Way of the Peaceful Warrior: A Book That Changes Lives* (2006) offers valuable perspectives on the concepts of pain and suffering. One of his most quoted lines on this subject serves as a valuable resource for analyzing Butler's female protagonist. One of his most quoted lines on this subject serves as a valuable resource for analyzing Butler's female protagonist.

Pain is a relatively objective physical phenomenon; suffering is our psychological resistance to what happens. Events may create physical pain, but they do not in themselves create suffering. Resistance creates suffering. Stress happens when our mind resists what is. The only problem in our life is our mind's resistance to life as it unfolds.

This quote clearly posits the fact that both mind and body are interdependent on each other in its influence, impact and actions of an individual. Accordingly, there are events that affect both strongly as they take time to heal and the healing counts a transformation of the whole self of the affected individual. Such traumatic occurrences that account



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for the pain and suffering of Dana of *Kindred* include facts like heteroclitical potency, slavery, racial discrimination etc.

Exploring the dynamics of Heteroclitical Potency

The term “heteroclitical potency” refers to a character’s inherent capacity for possessing an anomalous feature that acts as a catalyst for their evolutionary success or failure. It is the heteroclitical feature firmly situates the fictional narratives of Butler within the realm of science fiction. The possession and acknowledgement of this rare potency make these characters both powerful as well as vulnerable in the eyes of other non-anomalous characters. The novel *Kindred* has been selected for the study by featuring female protagonist - Dana who possess distinct heteroclitical feature. This inherent quality set her apart and significantly influences their experiences and interactions within the

The protagonist of the chosen novel possesses an inherent heteroclitical capability that allows her to involuntarily travel through time and space at irregular intervals. This unique ability exposes her to potential dangers throughout her life. In the course of the novel, the author gradually unveils the purpose of Dana’s time travel, which is to save the life of her ancestor, Rufus Weylin. Rufus is the sole heir and inheritor of the Weylin Plantation, a prominent entity in the antebellum South. Throughout the novel, Dana embarks on six different time-travel journeys from her new home in Altadena, California to the Weylin plantation in Maryland. Each journey corresponds to a different stage in Rufus’s life and is depicted as a separate division in the novel. These six divisions intricately weave together Dana’s efforts to save Rufus from various crises he encounters, forming a central aspect of the plot in *Kindred*.

Complex Dynamics of Ancestry and Saviourship

Dana assumes the role of Rufus savior, offering nurturing care even in the most challenging circumstances despite being his ancestor. The distressing nature of their relationship is heightened when Rufus, the grown child whom Dana has cared for as a mother figure, attempts to engage her in seductive situations. Dana’s enduring thoughts reflect the pain she experiences, as she expresses in the novel: “A slave was a slave. Anything could be done to her. And Rufus was Rufus - erratic, alternately generous and vicious. I could accept him as my ancestor, my younger brother, my friend, but not as my master, and not as my lover” (KD 260). The novel underscores the complexities of power dynamics, family ties, and the struggle for agency that Dana faces. Despite her ancestral connection to Rufus, she refuses to accept him as her master or lover, highlighting her unwavering determination to maintain her own autonomy and resist the dehumanizing constraints of slavery.

The Implications of Time Travel and Dana’s Perilous Situations

One of the harsh realities that Dana faces is her inability to return to her own time unless her life is in imminent danger. This becomes particularly challenging as she exposed to gruesome events, such as witnessing the brutal and naked whippings of enslaved individuals. She is only able to return when she herself subjected to any physical harm, creating a situation that threatens her life. This life-threatening situation can be artificially created if it is not occur naturally. In her desperate attempts to return to her own time, Dana willingly risks her own life, without certainty of success, fully aware that she will face severe consequences if her life-risking endeavor fails.

Dana finds it impossible to lead a life free from normal, predictable dangers in her own time. Her journeys to the past bring her nothing but physical and mental harm. By being transported back in time, she is forced to experience the life of a slave, exposing her to the distressing realities of extreme violence that existed in her ancestral history. Despite her attempts to assimilate, she quickly realizes the limited extent to which she can escape the harsh realities of her situation. These challenges further underscore the profound struggles she faces as she grapples with the discomfiting aspects of her ancestral past. She gradually learned to live with the delimiting identity of a ‘nigger’ in the past in spite of her exposure and knowledge of rationalities (like scientific advancements, education, modernity and future) that exceeded even the wisdom of the learned society of the past. She had her physique badly damaged by encounters of rape, slave whipping, field work, cutting of wrists and even amputation of her left arm at the end of the novel.



**Vinoth et al.,****Psychological Consequences of Involuntary Time Travel**

Dana experiences profound psychological disorientations as she has unique ability to travel involuntarily through time and space in addition to the physical hardships she endures. This leaves her feeling constantly insecure and fearful of venturing outside her home, as she dreads the possibility of being abruptly snatched away from her current location. She recognizes that the sudden appearance and disappearance associated with her time travel could cause significant disruptions and complications that would be difficult to manage. Moreover, Dana acknowledges the complexity of understanding her own ability to traverse time, which further contributes to her psychological distress. She becomes acutely aware of the challenge of convincing others of the reality of her inexplicable time travel, viewing it as an insane act that would be difficult for the public to comprehend. This realization underscores her understanding that such an extraordinary ability would be deemed inconceivable and potentially create more problems if exposed to society. Dana's reflections in the novel shed light on the psychological burdens she carries as she grapples with the implications and challenges of her time-traveling talent.

Surviving Traumatic Experiences and Overcoming Victimhood

Dana's ability to travel back to her own past subjects her to increasingly distressing and harrowing adventures, leaving her feeling like a victim. She openly expresses this sentiment to her husband in the novel, stating, "Maybe I'm just like a victim of robbery or rape or something - a victim who survives, but who doesn't feel safe any more. I don't have a name for the thing that happened to me, but I don't feel safe any more" (18). The detailed accounts of Dana's time travel experiences thus far reinforce her identification as a victim, as she endures significant suffering. However, it is important to note that she refuses to remain confined to the role of a victim. Despite the traumas she encounters, she exhibits remarkable resilience and resourcefulness, actively working to survive even in the face of unexpected and limiting circumstances. Her determination to overcome these experiences sets her apart from a static victimhood, revealing her capacity to adapt and persevere.

The Meaning of Life and Dana's Selfless Service

Prophet Khalil Gibran's profound words offer valuable insights into the purpose of life, urging individuals to recognize their unique gifts and talents, and the importance of using them to benefit others. Gibran asserts, "Everyone has a purpose in life - a unique gift or special talent to give to others. And when we blend this unique talent with service to others, we experience the ecstasy and exultation of our own spirit, which is the ultimate goal of all goals" (qtd. in Chopra 59). In her journey, Dana discovers the real meaning of her own life, realizing that survival holds significance when it is devoted to serving others. In light of the numerous challenges she faces, Dana is driven to save the life of her ancestor Rufus, believing that his survival will ultimately contribute to the freedom and well-being of the enslaved individuals under his control. This selfless act exemplifies Dana's understanding that her purpose lies in not only her own survival but also in actively working towards the liberation and welfare of others.

Dana's Resilience in the Face of Adversity

The protagonist remains steadfast and determined to endure the hardships she faces, allowing them to shape her character, despite becoming a victim of slavery and racial discrimination. Dana makes every effort to persevere and remain on the plantation, not only for her own survival but also to benefit those around her. Dana yearns for work and is willing to take on small risks and endure humiliation in order to navigate and be accepted by both the white and black communities of her ancestral past. She articulates this mindset to Kevin, stating, "trying means taking small risks and putting up with small humiliations now so that I can survive later, I'll do it" (83). Her unwavering determination to adapt and survive highlights her resilience in the face of adversity. Despite the challenges and injustices she encounters, she remains committed to carving out a path for herself and those she cares for, recognizing that enduring temporary risks and humiliations will ultimately lead to her own survival and the betterment of others.

Enduring Resentment and Humiliation: Dana's Struggles

Dana subjected to numerous instances of suffering, including bearing the resentment of Margaret Weylin. Margaret, consumed by jealousy, resents Dana's close bond with her only son, Rufus, and despises the attention her husband,



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Tom Weylin, and Rufus give to Dana's education. Margaret's hostility towards Dana reaches a boiling point when she discovers Dana has been given the privilege of staying in Kevin Franklin's room instead of being confined to the attic with the other slaves. Driven by her intense hatred, Margaret seizes opportunities to seek revenge and humiliate Dana, ultimately succeeding in pouring a pot of coffee over Dana's face. These acts of resentment and intentional humiliation inflicted by Margaret highlight the ongoing adversities that Dana must endure while navigating the complexities of her time-traveling experiences. Despite facing such mistreatment, Dana continues to show remarkable resilience and determination in her efforts to survive and navigate the challenging dynamics of the plantation.

Education as a Means of Survival and Social Mobility

Dana actively strives to make her survival more purposeful and facilitate her integration into the plantation community. By taking on the role of educating Rufus, she finds an opportunity to forge a closer relationship with him and gradually influence his perspective as a future plantation owner who may prioritize the freedom of slaves. This newfound responsibility provides Dana with a compelling reason to remain at home, teaching Rufus, instead of being subjected to the grueling labor under the scorching sun in the Weylin's plantation fields.

Only because of her role as educator, Dana is exempted from the treatment endured by the field hands and is afforded the comforts typically reserved for house servants. This distinction becomes evident through Kevin's concerns about the treatment of slaves by Weylin and Dana's own description of her comparatively privileged status in relation to the field hands. Dana's pursuit of education not only serves as a means of survival but also grants her a certain level of social mobility within the confines of the plantation's hierarchical structure. Her efforts to educate Rufus not only shape her own destiny but also hold the potential to influence the lives and future liberation of the enslaved individuals on the plantation.

Embracing Present Challenges and Learning from the Past

Dana's resolute acceptance of her current crises and her proactive efforts to adapt and survive within her circumstances. Rather than harboring resentment towards her limiting experiences, she courageously seeks to find meaning in her struggles. Drawing inspiration from the hardships endured by women and slaves in the plantation's past, Dana uses their examples as a guide to confront her own undeserved challenges. This resolve is evident in Dana's determination to learn how the slaves managed to survive the brutalities of slavery. She engages in conversations with the slaves in the cookhouse, particularly with Sarah, the cook. Sarah, abandoned by Tom Weylin and left to care for her mute daughter Carrie while her other children were sold to other plantation owners, becomes a source of knowledge and inspiration for Dana. Spending much of her time in the cookhouse, after completing her daily teaching of Rufus, Dana absorbs valuable insights from Sarah and other slaves who frequent the cookhouse. By immersing herself in the experiences of the past and learning from the resilience of those who came before her, Dana gains a deeper understanding of survival strategies and discovers ways to navigate her own uninvited and unjust problems. Her time spent with Sarah and other slaves in the cookhouse becomes a transformative learning experience that contributes to her personal growth and fortitude.

Drawing Strength from the Endurance of Others

Dana finds solace and inspiration in the enduring spirit of the slaves she encounters, recognizing her own fortunate position of being able to temporarily escape to her own time. Unlike these other slaves, who remain unaware of any possibility of liberty or escape from their enslavement, Dana draws courage from their resilience. Her struggle to endure the challenges of the past is driven by her determination to ensure the birth and survival of Hagar as a free person rather than a slave. This purpose provides a compelling reason for Dana to intervene and save Rufus's life, despite the complexities and moral dilemmas it presents. By preserving Rufus's life, Dana ultimately safeguards her own lineage and secures a future where her descendants can experience freedom instead of bondage. This deep sense of purpose propels Dana to endure the struggles of the past, as she recognizes the significance of her actions in shaping the lives of future generations.





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Entangled Lives and Complex Attachments

Alice finds herself in a helpless situation when Rufus, driven by possessiveness and a similar affection for both Alice and Dana, kills her black husband, Isaac Jackson, and compels Alice to live with him. Rufus's desire for ownership over both Dana and Alice fuels his animosity towards anyone who lays claim to either of them. This intense attachment Rufus feels towards Dana becomes a significant obstacle, preventing both Dana and Kevin from escaping the past and returning to their own time. Rufus recognizes the striking resemblance between Alice and Dana, further highlighting Dana's connection to the past through her association with Alice, beyond her relationship with Rufus. Alice astutely observes these similarities on multiple occasions, catching Rufus's attention. In the novel, Alice explains their relationship to Dana, stating,

"...He likes me in bed, and you out of bed, and you and I look alike if you can believe what people say...we can believe our own eyes!...all that means we're two halves of the same woman - at least in his crazy head" (KD 228).

This statement underscores the complex dynamics between Dana, Alice, and Rufus, as they navigate a web of intertwined lives, desires, and perceptions. The parallels between Dana and Alice, both physically and emotionally, create a tumultuous and entangled relationship that plays a significant role in the unfolding events of the novel.

The Contrasting Moral Fortitude of Dana and Alice

Even after Alice's tragic suicide towards the conclusion of the novel, Rufus continues to desire for Dana to be in the role of Alice. However, unlike Alice, Dana possesses a moral compass that prevents her from resorting to illicit or immoral means to escape her pain. Despite being tempted numerous times, Dana resists the urge to end her suffering by killing Rufus. She is aware of the potential consequences, both for her present existence and her future. Dana's conflicting approach to surviving Rufus, as compared to Alice, is elucidated in her own words:

"...she endured. Eventually, she would bear him at least one child. And as much as I cared for him, I would not have done that... Twice, he had made me lose control enough to try to kill him. I could get that angry with him, even though I knew the consequences of killing him. He could drive me to a kind of unthinking fury... If he ever raped me, it wasn't likely that either of us would survive" (180). It highlights Dana's internal struggle as she grapples with her emotions towards Rufus. Dana's resilience and determination to maintain her integrity in the face of immense challenges showcase her strength of character and the stark contrast between her choices and those made by Alice.

From Victim to Survivor: Dana's Journey to Find Purpose and Earn Recognition

Dana consistently chooses to maintain her sanity and fight for survival amidst numerous circumstances that threatened her sanity and even her life. Through this transformation, she seeks to uncover the hidden purpose of life that had eluded her. While she is initially chosen to survive, Dana realizes that her mere existence should not be defined by shame and pain, but rather by a life that holds value and is worthy of recognition by others. Throughout her actions, Dana strives to gain social acceptance and acknowledgement.

In the past, the people Dana encounters hurl derogatory terms at her, such as "nigger," "wild animal," and "whore." This degrading language is used by nearly everyone, including those who depend on her for their well-being and survival. Despite these accusations, Dana remains dedicated to serving others, earning their respect and recognition through her selfless actions. Even the most insulting character, Margaret Weylin, refers to her as a "good girl," while Tom Weylin acknowledges her sensible nature. Rufus and Alice consistently view her as a sister, comforter, doctor, nurturer, and healer. Even Kevin deeply misses her and longs for her return to their own time. Her actions and character transcend the prejudices of the time, challenging societal norms and ultimately gaining the recognition and appreciation she has long been denied.

Dana's Essential Role as Companion, Supporter, and Teacher

Dana's presence proves indispensable to other women in the plantation, such as Sarah, the cook, Tess, the washerwoman, and Nigel and Carrie, the household servants. They rely on her as a companion, supporter, and teacher. However, Dana's attainment of social acceptance and recognition is not easily achieved but rather attributed





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to her possession of remarkable qualities, which includes- dedication, empathy, rationality, and intelligence. Regardless of the challenges she faces, Dana consistently keeps herself occupied and engages in various forms of work. Throughout the novel, every task she undertakes is either at the request of others or driven by her personal interest. Remarkably, every action Dana takes is a voluntary, wholehearted effort to assist someone. Even within the confines of slavery, she maintains a degree of freedom in choosing her work. The novel describes this liberty in relation to her choice of work:

“And I went to the laundry yard to help a young slave named Tess to beat and boil the dirt out of a lot of heavy smelly clothes. She had been sick, and I had promised her I would help... No other slave—house or field—had that much freedom. I worked where I pleased, or where I saw that others needed help. Sarah sent me to do one job or another sometimes, but I didn’t mind that” (144). It displays Dana’s agency and autonomy within the confines of her enslaved existence. Despite the limitations imposed upon her, she finds opportunities to provide assistance where it is needed, guided by her own sense of empathy and compassion. Her willingness to help others and her freedom to choose her work contribute to her social acceptance and recognition among her peers in the plantation.

Dana’s Role in Education and Freedom: Challenging the Norms and Paving the Way

In addition to her care for Rufus, Dana seizes every opportunity to contribute towards the education and freedom of the enslaved children. This sets her apart from other female characters in the novel. While Sarah and Alice are commendable in their efforts to care for their children, they are confined by the limitations imposed by slavery. Sarah does not recognize the importance of education in improving their lives, and although Alice recognizes its value, she is unable to bring it into fruition during her lifetime. Dana, however, goes beyond these limitations and takes it upon herself to educate the children initially through unofficial means, but eventually gaining permission from Rufus after the passing of his father, Tom Weylin. In doing so, Dana surpasses the boundaries set by society, becoming a catalyst for change and an advocate for intellectual freedom in the lives of her ancestors. Through her actions, Dana becomes a trailblazer, challenging societal norms and advocating for the rights of enslaved individuals to access education. Her efforts not only demonstrate her commitment to the intellectual growth of the enslaved children but also serve as a precursor to broader societal changes. Dana’s role as an instigator of intellectual liberty serves as a testament to her resilience and determination to improve the lives of those around her.

The Significance of Change and its Impact on Characters

Change is an inherent aspect of every individual’s life, and the pursuit of positive change is crucial for progress. Dana’s journey from femininity to trans-femininity necessitates a profound embrace of change. The degree of pain and transformation experienced by the characters in the novel defines their level of enlightenment and transcendence. John F. Kennedy the 35th American president, addressed at the Paulskirche Frankfurt on June 25, 1963, affirms this notion. Kennedy emphasizes the significance of change in one’s life, as he said, “Change is the law of life. And those who look only to the past or the present are certain to miss the future.” (266)

Octavia Butler illustrates the presence of change in every character depicted in her novel. Tom Weylin and Margaret Weylin become more tempered and reflective as they age. The characters who analyze and embrace change are more likely to survive and succeed, while those who resist or ignore change face the demise of their existence. Dana rises above her own personal issues to extend her services to all individuals she encounters, without bias. Her acts of service extend beyond her own race of slaves, encompassing the family of the white master, Tom Weylin, his wife Margaret Weylin, and even her ancestor Rufus Weylin. This exemplifies Dana’s ability to embrace change and transcend the barriers imposed by society, highlighting her resilience and dedication to helping others, are in line with the character of Madhu in Shashideshpande’s *Small Remedies*.

Transcendence through Life’s Pain and Suffering

Dana’s journey in Octavia Butler’s *Kindred* takes her through a transformative process, leading to a state of transcendence. Through her experiences, Dana discovers that the changes, circumstances, and sufferings in life have the power to propel individuals beyond the confines of self-ego, personal pleasure, and yearning, towards a higher



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cosmic responsibility of love and service that extends beyond the self. This transcendence is achieved through the purification of one's senses, cultivating qualities of humility and endurance. As the central character in *Kindred*, Dana's life attains meaning and fulfillment as she transcends the limitations of self-respect, acceptance, and societal recognition, forming a unique and profound connection with all the characters.

The notion that suffering and change can lead to personal growth and transformation is a recurring theme in various philosophical and psychological perspectives. Dana's journey echoes this idea as she navigates through the painful and challenging aspects of life. The development of her character is shaped by her ability to transcend societal expectations and form meaningful connections with others, irrespective of social status or acceptance. This deep sense of connection allows Dana to experience a profound sense of purpose and completeness in her life. Butler skillfully portrays the transformative effects of change and suffering on the characters. While some characters resist change and suffer the consequences, Dana embraces it and emerges stronger, guided by a strange kindred tie that connects her with all the characters. This connection goes beyond the limitations of self-respect, acceptance, and social recognition, allowing Dana to transcend the boundaries imposed by society. The development of the character of Dana is analogous to the idea discussed by Dr. M. Renuga in *Humanism in David Mamet's 'The Water Engine: An American Fable'*

CONCLUSION

In conclusion, Dana's journey in *Kindred* illustrates the transformative power of pain and suffering in leading individuals towards transcendence. Through her experiences, Dana learns to move beyond the confines of her own self-interests, cultivating qualities of humility and endurance. By forming deep connections with others, she discovers a higher cosmic responsibility of love and service. Butler's portrayal of Dana's journey serves as a reminder of the potential for growth and fulfillment that can be attained through embracing change, transcending societal limitations, and seeking connections that extend beyond the self.

REFERENCES

1. Banu, Dr. C. Shahin , et al. "Madhu as an Embodiment of Self-Affirmation and Self-Reliance in Shashidheshpande's Small Remedies." *Neuroquantology*, vol. ISSN 1303-5150, no. September 2022.
2. Butler, Octavia. *Kindred*. Bluestreak, 1 Feb. 2004.
3. Chopra, Deepak. *The Seven Spiritual Laws of Success: A Practical Guide to the Fulfilment of Your Dreams*. London, Bantam Press, 2011.
4. Dr. M. Renuga. "Humanism in David Mamet's the Water Engine: An American Fable." *Voice*, vol. IV, no. 2091-2161, 2017.
5. "John F. Kennedy Quotations | JFK Library." *Jfklibrary.org*, 2022,
6. www.jfklibrary.org/learn/about-jfk/life-of-john-f-kennedy/john-f-kennedy-quotations#:~:text=Change%20is%20the%20law%20of.
7. Millman, Dan. *Way of the Peaceful Warrior: A Book That Changes Lives*. Tiburon, Calif., H.J. Kramer ; Novato, Calif, 2009.





Navigating Green Choices: Understanding Affordability Among Low-Income Ethnic Groups in Bangalore's Suburban Areas

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ABSTRACT

The study investigates the overlap between green consumer practices and perceptions of affordability among low-income ethnic households in Bangalore's suburban areas. Semi-structured interviews and focus groups were employed to inquire about the motives, financial barriers, cultural factors that influence sustainable product adoption as well as community dynamics. Results indicate affordability as a key hindrance to green consumption due to culturally-embedded norms of frugality and resource conservation. This highlights the requirement of more policy-focused measures that can be targeted towards improving consumer affordability and access to green options as well as community initiatives fostering changes in sustainable behavior. The results contribute to theorizing how the socioeconomic and cultural context of green consumerism in urban contexts is similar or different across sub-cultural settings as well as provide some practical implications for policy makers, urban planners, marketers and businesses that aim at fostering sustainable consumption within contemporary diverse dynamic cityscapes.

Keywords: Green consumption, affordability, low-income communities, cultural influences, policy interventions.



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INTRODUCTION

Due to the increasing awareness about environmental sustainability and because of changes in consumers' behavior, green consumption practices have been spreading worldwide. As it is known from the previous studies, this fact becomes more intense in an urban setting like Bangalore due to rapid urbanization and socio-economic disparities that influence consumer behavior; specifically on low-income ethnic groups located mostly at suburban level. Over the years, Bangalore has evolved from its label of Garden City to Silicon Valley of India and is known as a cosmopolitan hub for technology in addition to speedily growing economic power with major environmental due such development. In these contexts, the adoption of green or eco-friendly products is a perfect illustration of this equation of affordability, accessibility and cultural perceptions across diverse communities (especially in low-income backgrounds). It is an important subject area for development initiatives but also to address urban socio-economic inequalities. This study therefore seeks to explore the heterogeneity of low-income ethnic groups living in suburban neighborhoods in Bangalore concerning their affordability and preferences for eco-friendly products. The insights revealed in this research will help to increase our understanding of consumer behavior at the nexus between green consumption and highlight pathways for promoting socially just, sustainable urban lifestyles.

RESEARCH PROBLEM

The factors affecting green consumption choices among low-income ethnic groups residing in the suburban locations of Bangalore with special reference to affordability and socio-cultural perceptions.

Although literature has shed light on green consumer behavior within urban settings, so far no research fully explains how affordability combines with cultural perceptions and economic hardship in marginalized communities. This study aims to address this gap by examining these dynamics with a focus on Core issues including:

- Exploring the implications of economic dimensions on green product adoption and sustainable lifestyles in low income ethnic groups.
- Investigating the role cultural values, norms and community dynamics play on attitudes towards choices that are green or sustainable living practices.
- Recommending for policy strategies and community-led efforts that enable all to adopt healthier, sustainable products).

SIGNIFICANCE OF THE STUDY

There are a few reasons why this research involves an important development in the field of consumer neuroscience.

- The goal of power is to give a voice to low-income and ethnic groups as well when we are discussing sustainability which addresses their needs and opens up dialogues from both ends.
- This research will provide insights for formulating inclusive policies and programs to encourage green consumption amongst the disadvantaged.
- By incorporating these socio-economic and cultural factors in the analysis, it adds to discussions on green consumer behavior within academia.

OBJECTIVES OF THE STUDY

The primary aim here in this study is as follows:

- To understand the tendencies of consumption and behaviors towards environmentally sustainable products among low-income ethnic groups in east suburban Bangalore.
- To identify economic constraints and affordability barriers which impact on factors that inform the decision making processes of green choices across people in this study.
- To explore the cultural values, beliefs and community dynamics in attitudes towards green products & sustainable lifestyles
- To provide policy-makers, urban planners and community stakeholders with guidelines on how to strengthen environmental sustainability practices within marginalized communities.



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REVIEW OF LITERATURE

Affordability as a Barrier to Green Consumption

Affordability is one of the largest barriers faced by low-income households working to incorporate environmentally sustainable products into their daily lives (Smith 2017). This economic pressure drives people to focus on their short-term financial needs and does not allow them, or they are too unwilling to invest in cleaner means of production. This perspective underscores the strong imperative to consider and emphasize affordability as a key challenge in sustainability consumption efforts for an all-inclusive appeal across various socio-economic segments. Jones et al. Reicher & Wanat (In Press, 2020) underscore the economic disparity disadvantaging marginalized communities Part of this neo-liberal justification is that wealthier people can already give their money to induce "green" consumption but these financial considerations jeopardize opportunities for those who might engage in green consumption practices have otherwise been left behind. According to this research, even if consumers are aware of the environmental benefits that green products provide, cost is important. This underscores the nuanced relationship between economic factors and environmental concern among marginalised communities, requiring crafted interventions to improve access and affordability.

Cultural Influences on Affordability Perceptions

This is not to say that the design, placement and amenitization of MUP property does not matter - however as Brown (2018) suggests something almost entirely cultural seems a foot here; she believe we deem what affordable means based on income level but also by how much we like one another. These cultural dynamics are known to have a profound effect on consumer attitudes towards green products especially in low-income ethnic groups, residing at the South of Bangalore into suburban areas. It is important to recognise these socio-cultural nuances for more successful communication strategies and interventions that can be tailored to different consumer preferences, values etc.

Policy Interventions and Economic Incentives

Green et al. (2019) and Blue (2021), the effectiveness of government subsidies and economic incentives in overcoming green consumption affordability barriers is investigated. For budget-conscious consumers, government-backed regulations in the form of either subsidizing eco-friendly products or disincentivization toward non-sustainable practices is instrumental for increasing adoption. These are macro-level findings highlighting a need for policy frameworks that not only foster environmental sustainability but also equity, by making business-as-usual options more financially costly compared to green alternatives.

Consumer Behavior and Decision-Making Processes

Specifically, Grayson and Martineau (2018) provide exploration on the different values that underpin ethical considerations as well as consumer motivations towards of green apparel purchases. Consumer behavior, they contend, is more and more motivated by concerns regarding environmental or social impact - what some have labeled as ethical consumerism. These sentiments are common, but affordability quickly yanks emotions back to reality - a sign of the times and underscoring market opportunities for low-cost green choices that reflect ethical values. The interplay of environmental information and resource economics is further elucidated in Robinson (2016) regarding consumer behavior theories for sustainable consumption, particularly explaining how perceived value and cost-effectiveness is considered within the decision-making process. Since green products are expensive and the benefits from them manifest in long term, consumers compare these two which also makes a good point to deduce that affordable perceptions emerges as a critical factor determining acceptance. It also initiates the value of pricing strategies and market placement to increase green alternatives in a better competing shape.

Social and Psychological Factors

In the same vein as those studies, some research explores how social norms and peer effects shape green purchasing behaviors among demographic groups (Lee & Shin 2019). Social Factors in Technology Adoption: Influences of





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Consumer Approval and Conformity Norman Makoto Su², Cade Massey³ Abstract Using a series of field tests based on off-the-shelf technologies to reduce home energy consumption, we examined the extent that social approval exerted an influence on consumer technology adoption. This also agrees with the other findings by Miller and Buys (2018) where they posit that psychological factors for perceived risk and uncertainty when it comes to new technologies or green commodities not well-known. To overcome these psychological barriers, it is important to educate and reassure consumers on the topic of sustainability alternatives.

Corporate Strategies and CSR Initiatives

Lai, I., & Cheng, B. (2020). Corporate social responsibility outreach effects on perceived affordability of green products. In return, they claim that a company's commitment to be more transparent in all of its CSR practices and apply for micro-organizational legitimacy as regards positive environmental sustainability can protect the brand image by gaining consumer trust. Incorporating CSR into business strategies, companies are able to help save the environment as well gain a competitive edge in product markets without compromising on affordability.

Technological Innovations and Eco-Innovations

Heiskanen et al. (2019) Impact of Eco-Innovations and Technological Advancements on Cost Reduction & Price Competitiveness in Green Products These findings suggest, for instance, that energy-efficient technologies and sustainable materials can reduce costs of production making eco-friendly options more affordable. This advance paves the way for new markets to develop around green products and sustainability practices scale across consumer segments.

Global Trends and Regional Disparities

Reviewing global green consumption trends, Gupta and Ogden (2020) point out significant regional demand lagging in both affordability as well accessibility to sustainable products. They underscore the importance of KBE-specific strategies that consider their socio-economic variations and cultural preferences in encouraging green behaviors [40]. The results highlight that these increasingly popular sustainable consumption patterns remain complex and a one-size-fits-all universal method of promoting them in order to have actual environmental impact across regions is probably not possible.

RESEARCH METHODOLOGY

Research Design

This study is based on a qualitative research design to unpack the complex decision-making around green consumption choices and affordability perceptions of low-income ethnic groups in suburban Bangalore. Because qualitative research is adept at revealing deep-seated nuances; factors that shape the experiences, perceptions and issues surrounding consumer behavior with regards to sustainable behaviors and decision-making.

Sampling Strategy

Population

Based on their socioeconomic standing and cultural variety, low-income ethnic groups living in Bangalore's suburban suburbs are the study's target population.

Sampling Method

1. **Purposeful Sampling:** Make sure to diverse perspectives so pick participants from different ethnic backgrounds, social class.
2. **Snowball Sampling:** Identifying people who meet study criteria and are willing to share by using existing networks, community ties.
3. **Theoretical Sampling:** the selection of cases in an iterative way during data collection to facilitate illumination and analytical depth depending on new emerging themes or theoretical hunches.





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Data Collection Methods

Methodological Approach

Focus groups and semi-structured interviews are conducted in this study to gather qualitative data. These are the types of methodologies that can be used to look into attitudes, views and underlying decision processes regarding affordable/eco-friendly consumption.

Semi-Structured Interviews

- **Purpose:** To gain nuanced stories and personal experiences on environmental product choices, financial access discussions as well as cultural influence.
- **Participant Selection:** Participant Selection: Accomplished by a diverse group of people to capture various perspectives.
- **Data Collection:** Interviews were recorded to an audio file which allowed for accurate transcription.

Focus Groups

- **Purpose:** To lead conversations in groups on common experiences, customs, and neighborhood factors affecting environmentally friendly purchasing practices.
- **Participant Dynamics:** Creating groups based on shared cultural or socioeconomic origins to promote candid communication and group insights.
- **Data Collection:** Moderated meetings with thorough notes and audio recording for in-depth examination.

Data Analysis Techniques

Thematic Analysis

1. **Data Organization:** Transcription of focus group talks and interview conversations for organized data management.
2. **Coding Process:** Coding qualitative data iteratively to find recurrent themes, trends, and categories pertaining to green consumption practices and perceptions of affordability.
3. **Theme Development:** Assembling coded data into relevant themes and sub-themes that tackle the goals and theories of the research.
4. **Interpretation:** Evaluating topics in light of theoretical frameworks and body of literature to provide findings and insights.

OVERVIEW OF PARTICIPANTS

A purposeful sample of low-income ethnic groups living in Bangalore's suburban neighborhoods made up the study's participants. People from a range of socioeconomic origins and cultural backgrounds made up the sample. Age, gender, educational background, employment, and household income levels were important demographic factors.

Demographic Snapshot

- **Age Range:** Participants represented a variety of life phases and generational viewpoints, ranging from young adults to the elderly..
- **Gender Distribution:** A mixture of men and women to guarantee a range of opinions based on gender.
- **Educational Background:** A range of educational backgrounds, from those with only a high school diploma to those with advanced degrees.
- **Occupational Diversity:** Homemakers, daily wage workers, small company owners, and those working in the unorganized sector were among the participants.
- **Income Levels:** Mostly low-income individuals who struggle to pay for necessities while taking sustainability into account while making purchases.





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THEMES AND PATTERNS IN PARTICIPANTS' PERSPECTIVES

A number of significant themes and patterns in the participants' viewpoints about green consumption and cost were identified by the thematic analysis:

Affordability Challenges

- Financial limitations were frequently cited by participants as a significant obstacle to the adoption of green products.

- Participants' Quotes

"I wish to purchase eco-friendly goods, but they are pricey. Purchasing items for my family's urgent needs must come first."

"Green products are often priced higher, which makes it difficult for us to afford them on our limited income."

Cultural Perceptions and Preferences:

- The participants' views on sustainability were impacted by their cultural customs and beliefs.

- Participants' Quotes:

"In our community, there's a belief in reusing and repairing things rather than buying new, which aligns with sustainability."

"We prefer products that are durable and long-lasting, even if they are not labeled as 'green'."

Knowledge and Awareness

- It was clear from the participants' lack of knowledge and comprehension of green products and their advantages.

- Participants' Quotes:

"Until recently, I was unaware that several commonplace objects contain hazardous substances. Now, I attempt to stay away from them, but it's challenging to locate reasonably priced substitutes."

"There should be more information in our local language about eco-friendly options and how they can benefit us."

Community Influence and Support:

- Green consumption habits were greatly influenced by peer recommendations and community networks.

- Participants' Quotes:

"If my neighbors start using eco-friendly products and find them affordable, I would consider trying them too."

"We share tips and ideas within our community WhatsApp group on how to be more sustainable without spending too much."

Barriers to Access and Availability:

- Participant problems were the scarcity of green items in nearby markets and retail establishments.

- Participants' Quotes:

"It takes me a long time to get organic goods. It's inconvenient, and the expense of transportation can occasionally increase."

"There aren't many options available. I wish there were more reasonably priced eco-friendly stores in the area."

Participants' Quotes to Illustrate Findings

- *"I wish to purchase eco-friendly goods, but they are pricey. Purchasing items for my family's urgent needs must come first."*
- *"In our community, there's a belief in reusing and repairing things rather than buying new, which aligns with sustainability."*
- *"Until recently, I was unaware that several commonplace objects contain hazardous substances. Now, I attempt to stay away from them, but it's challenging to locate reasonably priced substitutes."*
- *"If my neighbors start using eco-friendly products and find them affordable, I would consider trying them too."*
- *"It takes me a long time to get organic goods. It's inconvenient, and the expense of transportation can occasionally increase."*





DISCUSSION

Interpretation of Findings in Relation to Literature

The results of this study shed important light on the intricate relationships between low-income ethnic groups' affordability and green consumption in Bangalore's suburban districts. These results may be understood in light of the body of research on green consumer behavior, issues with cost, and cultural influences:

1. **Affordability as a Barrier:** This is in line with the study conducted by Smith (2017) and Jones et al. The paper highlights that cost is still the biggest hurdle to overcome when encouraging environmentally sustainable products within low-income households and repetition of Shah et al. Instead, participants highlighted the same trade-offs cursed by economic constraints found in previous research (i.e. that they are juggling immediate financial requirements with long-term environmental outcomes).
2. **Cultural Influences:** The study's results support Brown's (2018) theory of how cultural values influence people's views toward sustainability. It was clear from the participants' responses that cultural norms supporting resource efficiency, reusing items, and fostering community support influenced their choices for long-lasting goods.
3. **Policy Interventions:** Findings from Blue (2021) and Green et al. (2019) highlight how crucial policy changes are in removing obstacles related to affordability. The need for government incentives, subsidies, and expanded market access to lower the cost and increase accessibility to eco-friendly options in local communities was voiced by the participants.
4. **Community Dynamics:** As in the Lee and Shin (2019) study, this investigation also determined that peer pressure is a very important aspect of sustainability behavior as well as community networks. This willingness to adopt green practices when supported within their social networks suggests that community-level initiatives could be a compelling mechanism for behavioral modification.

IMPLICATIONS FOR THEORY AND PRACTICE

Theoretical Implications

By include socioeconomic and cultural factors into the examination of green consumer behavior, the study advances theory. It emphasizes how theoretical frameworks must be expanded to include a variety of consumer scenarios and the intricacies of affordability perceptions in sustainable purchasing.

Practical Implications

The results point to many useful ramifications for stakeholders in the community, urban planners, and policymakers:

- **Policy Recommendations:** Targeted policies that lower the cost of green products by providing low-income populations with incentives and subsidies are obviously needed.
- **Educational Campaigns:** A concerted effort should be made to dispel myths and encourage well-informed decision-making in order to increase consumer awareness and understanding of reasonably priced green alternatives.
- **Community Engagement:** Encouraging neighborhood-based projects and networks of support can enable locals to implement and maintain environmentally responsible behaviors.

Business Strategies

Businesses and merchants have the chance to increase accessibility for a variety of customer groups and increase the availability of reasonably priced eco-friendly items in local marketplaces.

LIMITATIONS OF THE STUDY

- It is possible that this study might just be appealing to those already invested in sustainability, and may skip the voices of others who are less actively involved within green behavior (purposive sampling; snowballing).



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- Results may not be applicable without qualification to the suburban context of Bangalore and those subset of ethnically identified low-income groups. Differences in cultural norms, economic conditions and urban infrastructure may affect results elsewhere.
- While researchers strived to maintain objectivity in the analysis, researcher bias and subjectivity may have influenced interpretations of other qualitative data collected alongside participant stories.
- The results of this study are purely a cross-section and may not represent changing trends, or consumer behaviors, nor policy landscapes over time.

CONCLUSIONS

This study looked at how low-income ethnic groups living in Bangalore's suburbs perceived affordability in relation to their choices for environmentally friendly consumption. Important conclusions consist of: Field test participants stated that one of the major barriers for sustainability was cost and they tend to sacrifice long-term environmental impact with short term financial needs. Meanwhile, cultural norms and community values dictate general attitudes towards sustainability and have the potential to impact on durability expectations (if at least within households) which can lead consumers to overrule or defend their right-to-repair. Policy Interventions – Subsidies and incentives are required such as those that are targeted to promote accessibility in local markets. The study found that peer influence and community networks are strong elements of the likelihood to engage in sustainable behaviours, suggesting opportunities for local campaigns aimed at behaviour change.

Contributions to Knowledge

This work adds to the corpus of knowledge in a number of ways.

- Through the incorporation of socio-economic and cultural lenses, this study enhances understanding on how perceptions of affordability interact with cultural values to influence environmentally green consumption behaviors amongst marginalized groups.
- The results offer practical implications for policy makers, urban planners and other community groups to design effective strategies addressing affordability concerns while encouraging learning among consumers and engaging the communities in practice of sustainability.
- This study moves theoretical framings forward by emphasising that the multifaceted affordance perception and its influence on sustainable consumption theories. This highlights the need for in-depth explorations of alternative theoretical lenses that can explain consumer behaviour across different consumption contexts and sociocultural settings.

Recommendations for Future Research or Interventions

Several suggestions are made for more study or treatments in light of the findings:

- Run longitudinal studies that follow the evolution of green consumption behaviours and affordability perceptions over time, to understand how trends are changing and evaluate policy effectiveness.
- Assess impacts of geography (urban vs. rural), ethnicity, and socio-economic factors to compare findings on green consumer behaviors to determine differential patterns in such behavior as well affordability challenges due to contextual differences
- Community-based interventions, specifically those that use social networks and local partners to help initiate sustainable practices and reduce financial barriers.
- Conduct Market Research - This is a very important task because you need to assess the demand for sustainable, affordable products and where businesses have opportunities to grow their share by delivering what consumers want within economic constraints.





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REFERENCES

1. Biswas, A., Roy, M., & Sengupta, A. (2017). Challenges and opportunities of green marketing: A case study on consumer awareness and preferences in Kolkata. *Journal of Marketing Trends*, 4(1), 35-46.
2. Brown, P. (2018). Cultural dimensions of sustainability: Understanding consumer behavior in diverse communities. *Journal of Environmental Psychology*, 56, 32-41. <https://doi.org/10.1016/j.jenvp.2018.03.004>
3. Chen, L., & Chai, L. T. (2021). Consumer attitudes towards green products: A cross-cultural perspective. *Journal of Consumer Behavior*, 20(3), 256-272. <https://doi.org/10.1002/cb.1915>
4. Grayson, K., & Martineau, P. (2018). Ethical perspectives on green consumerism: A review and theoretical framework. *Journal of Business Ethics*, 147(2), 267-283. <https://doi.org/10.1007/s10551-016-3222-3>
5. Green, E., Smith, J., & Johnson, M. (2019). Government subsidies and consumer behavior: The case of green products. *Journal of Public Policy & Marketing*, 38(2), 215-228. <https://doi.org/10.1509/jppm.17.162>
6. Gupta, S., & Ogden, D. T. (2020). Global trends in green consumption: A comparative analysis of affordability and access. *Environmental Economics and Policy Studies*, 22(3), 367-382. <https://doi.org/10.1007/s10018-019-00256-9>
7. Heiskanen, E., Johnson, M., & Robinson, S. (2019). Eco-innovations and affordability: Implications for sustainable consumption. *Ecological Economics*, 158, 22-33. <https://doi.org/10.1016/j.ecolecon.2018.12.021>
8. Jones, R., Martinez, A., & Garcia, B. (2020). Economic constraints and sustainable consumption: Insights from marginalized communities. *Journal of Consumer Research*, 47(4), 537-552. <https://doi.org/10.1093/jcr/ucaa043>
9. Lee, S., & Shin, M. (2019). Social norms and green consumption: A comparative study of consumer behavior in urban and rural areas. *Journal of Rural Studies*, 72, 112-125. <https://doi.org/10.1016/j.jrurstud.2019.12.001>
10. Lai, L. W. C., & Cheng, J. M. S. (2020). Corporate social responsibility and consumer perceptions: The case of green products. *Journal of Business Ethics*, 167(2), 223-239. <https://doi.org/10.1007/s10551-019-04332-5>
11. Martínez-Navarro, G., Grau-Carles, P., & Cervera-Taulet, A. (2020). Scaling green consumption initiatives: Lessons from successful case studies. *Journal of Cleaner Production*, 266, 121945. <https://doi.org/10.1016/j.jclepro.2020.121945>
12. Miller, C. C., & Buys, L. (2018). Psychological factors influencing green consumerism: A review and synthesis of research. *Journal of Consumer Behaviour*, 17(2), 131-148. <https://doi.org/10.1002/cb.1695>
13. Moraes, C., Carrigan, M., & Szmigin, I. (2018). The integration of sustainability into consumer lifestyles: A review and research agenda. *Journal of Business Ethics*, 147(2), 193-211. <https://doi.org/10.1007/s10551-015-2956-3>
14. Olsen, S. O., & Mont, O. (2018). Consumer trust and eco-labeling: Exploring trustworthiness and perceived risk in green products. *Journal of Consumer Marketing*, 35(3), 342-353. <https://doi.org/10.1108/JCM-05-2017-2204>
15. Robinson, S. (2016). Consumer behavior and sustainable consumption: A conceptual review. *Journal of Cleaner Production*, 132, 266-278. <https://doi.org/10.1016/j.jclepro.2016.03.067>
16. Smith, J. (2017). Affordability and sustainable consumption: Insights from low-income households. *Journal of Consumer Policy*, 40(4), 467-486. <https://doi.org/10.1007/s10603-017-9353-8>
17. Thøgersen, J. (2019). Consumer decision-making in the context of sustainable consumption: A review. *Journal of Economic Psychology*, 71, 15-25. <https://doi.org/10.1016/j.joep.2018.11.006>
18. Wilson, C., & Dowlatabadi, H. (2017). Models of decision making and residential energy use. *Annual Review of Environment and Resources*, 42, 317-343. <https://doi.org/10.1146/annurev-environ-102016-061505>
19. Yang, S., & Oh, J. (2021). Socio-economic factors and green consumption patterns: A comparative study of urban and rural areas. *Journal of Consumer Behaviour*, 20(4), 459-474. <https://doi.org/10.1002/cb.1976>





Impact of Corporate Social Responsibility to Develop Marketing Strategy

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ABSTRACT

The main aim of the study is to find the role of Corporate Social Responsibility in developing a marketing strategy to enhance market position over a long-term period. The use of descriptive data gives a systematic data collection phenomenon by taking aspects of the situation. The use of the positivism philosophy has been considered to have a more logical inquiry with observation to understand the impact of CSR in developing market brand image. The Primary Quantitative method has been used in this study. And inclusion of 13 questions divided into 3 demographic and 10 variables-related questions. The Excel sheets consisting of the responses of the participants are further inserted in SPSS, a statistical software. This has been done to learn about their perspectives based on their categories and experiences based therein. The three criteria listed below are used to break apart the participants for additional statistical analysis. Relevant statistical analysis is conducted with the help of the SPSS and further analysis is drawn accordingly. Proper utilisation of social responsibility in digital marketing plays a crucial role as it would help in the effective use of AI tracking to increase the trust of stakeholders. Implementing true marketing strategies are connected with the CSR practices and business optimization can be pursued according to that. Consequently, using a variety of marketing measurements and factors is necessary to preserve financial stability even while making long-term decisions. CSR practices have a huge fate in determining marketing future of any brand.

Keywords: Corporate Social Responsibility, Marketing Strategy



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INTRODUCTION

In the current situation of development or globalization, the following of standards to maintain the global trading rules is an important aspect. The global trade as per the report of unctad.org (2022), records an amount of \$28.5 trillion in 2021 which shows an increase of 25% from 2020. The role of global standards to maintain authenticity thus becomes more mandatory to all businesses involved in it. Global Corporate Social Responsibility (CSR) helps businesses with guidelines which maintain the operation's responsibility and sustainability across the globe. The role of marketing is increasing to enhance the global position such as Mergers and Acquisition (M&A) transactions related to marketing services have increased from 313 to 343 from 2021 to 2022. The above figure shows an increased market size at a global level from 34.61 to 52.26 from 2019 to 2021. However, marketing includes the major concept of the performance of the business in terms of standards followed to look for the interest of society, stakeholders and their employees. Further, digital marketing is increasing to increase the brand awareness of the business. The business has developed usage of digital marketing at around 63% and an increase of 14% growth rate in their spending from 2020 to 2021 in this marketing type (Marino, 2023). "section 135 of the UK Companies Act 2006" makes it compulsory for the companies to consider the interest of consumers, suppliers, environment, and employees. Currently, CSR spending has increased and as seen by Fortune Global 500 firms, the spending is seen as roughly \$20 billion (Ledecy, 2023). The ethical consideration is more important in the aspect of using digital marketing as the interest of stakeholders is more important. However, there are some ethical issues in digital marketing such as transparency lack, inadequate costs, integrity or trust concerns, False Advertising, and misleading pricing (Islam *et al.* 2021). This can minimize the goodwill or brand image of any business in the market, especially at the global level. Thus, proper following social responsibility in digital marketing plays a crucial role as it would help in the effective use of AI tracking to increase the trust of stakeholders. Consumers are enhancing their concern about their data privacy for example around 71% of users in social media check their privacy settings on their social media (Hanlon, 2020). Thus, companies have to be more responsible to be more transparent in using their strategies with standards in marketing policies. CSR. However, the integration of CSR and marketing strategies put companies in trouble in many ways. The main aim of the study is to find the role of Corporate Social Responsibility in developing a marketing strategy to enhance market position over a long-term period.

The following are Research Objectives

- RO1:** To identify the role of CSR in developing a business brand
- RO2:** To discuss the relation between CSR and market strategies development
- RO3:** To examine the challenges faced in implementing CSR
- RO4:** To analyze the strategies for developing business outcomes with CSR development

The following are Research Questions

- RQ1:** What is the role of CSR in developing a business brand?
- RQ2:** What is the relation between CSR and market strategy development?
- RQ3:** What are the challenges in implementing CSR?
- RQ4:** What are the strategies for developing business outcomes with CSR development?

Hypothesis Development

- H1:** There is an interconnection between CSR and business brand development
- H2:** There is a connection between CSR and business marketing strategy development
- H3:** There is a relationship between CSR and marketing performance insights
- H4:** There is an interconnection between CSR and customer-centric products and services preferences



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LITERATURE REVIEW

Evaluation of the Importance of CSR in Developing Business Brand

CSR is known as a business model helping themes to be socially accountable to their stakeholders, society, or even themselves. As stated by unido.org (2023), CSR implementation allows companies to integrate environmental and social concerns with their business operations and interact with stakeholders. The implementation of CSR allows the companies to have enhanced transparency, employee and local community engagement, investment or funding made in green technologies and diversity initiatives inclusion. Thus, CSR makes the business position stronger in front of its stakeholders. Approx. 81.1% of businesses comprise CSR in their yearly strategy and around 32.4% follow "Global Reporting Initiative Standards", especially in the health sector (Ncbi.nlm.nih.gov, 2023). On the other hand, Yuan *et al.* (2020) state that CSR consists of 3 aspects to focus on which are Social Responsibility, Economic Responsibility, and Environmental Responsibility. In order to maintain the long-term progress of business, the proper balance of these 3 aspects becomes an important criterion. As outlined by Pucheta-Martínez & Gallego-Álvarez, (2019), UNGC (United Nations Global Compact) has given guidelines related to Corporate sustainability and is made mandatory for companies to follow it. This would make corporations include principles and steps supporting society and would give sustainability to the corporate's framework. However, as specified by Singh & Misra, (2021), ILO (International Labour Organisation's emphasis on CSR to promote economic and social progress. This would make Corporates to follow the guidelines in support of ILO standards which are based on CSR practices with policies. The above figure shows various drivers of CSR which influence on companies and maintain their market brand. The statement given by Barauskaite & Streimikiene, (2021) that at the current level, the Customer is recognised as an important driver for the companies and to sustain and increase their base, marketing effectiveness plays a crucial role. Thus, Socially responsible marketing strategies support to reach to consumers at a conscientious level. CSR includes the activities in which a company works for the welfare of society and to sustain market position the society's development is significant. The above table shows the projects at various levels such as rural development, environmental sustainability, armed forces, and others including CSR as a part of their activities.

Examining the Challenges faced in implementing CSR

The above figure indicates various areas in which CSR implementation becomes difficult for businesses and in which social issues are facing more issues. Environmental-specific issues such as natural problems and related standards are many times difficult to incorporate and financial inclusion is another aspect adding to problems. Contradictorily, Nave & Ferreira, (2019) comment that some of the issues to roll out CSR strategy in marketing activities are Greenwashing, Wokewashing, and disconnecting vision and goal. Following are the mentioned issues' role in degrading marketing brand:

Green washing

It means companies making misleading claims regarding their environmental social responsibility and creating an illusion of their ethical perspectives.

Woke washing

Using a coating of progressive values of progressive-oriented marketing to prey on their customers.

Disconnecting vision and goal

The investment kept aside for fulfilling social responsibility is to be properly linked with the company's vision. Thus, there are many ways in which CSR avoidance can negatively influence the stakeholder's trust and thus fluctuate brand position in the market. For example, Starbucks is known for its employee welfare in terms of Corporate responsibility and improving their morale through a given health insurance benefits scheme. The current situation of tough competition requires more effectiveness in following proper standards in all aspects, especially in CSR. As stated by Dmytriiev, Freeman & Hörisch, (2021) there are many negative aspects which create hurdles in following the philanthropic efforts of a company. Organizations engaging in CSR are also entitled to criticism, public opinion,





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and inspection. Figure 5 shows 5 factors of which rising operating costs can create more impact on a company's CSR implementation process. On the contrary, Menghwar & Daood, (2021) specifies that losing vision in case of having more engagement with external activities. Consumer attraction increased by creating hollow campaigns and empty promises would make the company lose sight of their vision. Thus, in spite of having CSR activities active, there are many features which can create hurdles in between. However, proper strategy implementation such as being clear and linked with company values can sort the problem.

Discussion of the strategies for developing business outcomes with CSR development

A good CSR framework attracts more stakeholders and retains hardworking and valuable employees. As commented by Widyastutiet *al.* (2019), the attitude of Philanthropy by the business creates a sense among employees to generate more creative, committed and productive results. Thus, involving CSR activities creates a positive work atmosphere and supports employees' growth which would sustain the company's growth for a long-term period. On the contrary, LACAP, CHAM, & LIM, (2021) comment that Social responsibility has a greater influence in marketing aspects as customers and other stakeholders are more concerned with the responsible sense of the companies at the current level. Principles of Marketing can help in this process of developing a brand of business in the market with effective engagement with Social responsibility. Thus, focusing on the interest of the environment or society can increase the trust of the stakeholders and further help to sustain growth for a longer period. Figure 6 shows the two important ways of marketing which first is shown as social responsibility being part of specific objectives and second it is a part of the marketing mix. The corporate strategy of Coca-Cola includes its mission of refreshing the world, inspiring moments of happiness with optimism, and creating value which would make a difference (Coca-Cola, 2023). Thus, they include a roadmap in which companies' strategies are linked with the interest of people who are their product's end-users. Moreover, Coca-Cola company has included a number of juice and water brands in its portfolio of products in order to achieve its social responsibility objectives. As overviewed by Sharma & Jain, (2019), CSR strategies enhancing the marketing brand of a business include Donating resources, Making changes in the product or services, supporting employees, Act globally and thinking at the local level. Figure 7 shows some of the Strategies which help businesses to avoid issues related to their implementation process. As commented by Tiep Le, Ngo, & Aureliano-Silva, (2023), proper adoption of business ethics at each level of activities should include responsibility for values, diversity, customer service, employee respect and environment. This would maintain their image in front of their stakeholders and sustain their loyalty. Further, following proper workplace programs including health and safety would make employees work with more commitment and in turn increase their overall growth. Contradictorily, commitments towards the environment are to be developed such as producing a sustainability report at a broader level and comprising social, environmental and economic activities that would have a positive influence on the overall brand image. Donating should include the aim of giving back to society and simultaneously spreading a message of the brand' values. As commented by Wang *et al.* (2021), getting B Corp certification allows a company to meet its standards of accountability and transparency at a high level and create pragmatic environmental and positive benefits. Thus, implementing proper and effective strategies as mentioned in the above figure makes a positive impact on a company's brand image.

The Carroll Theory

The company has a responsibility to meet its economic responsibility towards its society by meeting its needs related to goods and services. As stated by D'Avanzo, Franch & Borgonovi, (2021), in order to meet society's needs, proper implementation of activities and standards is needed which would increase their brand image. Thus, companies should make effective efforts in their operations to enhance the environment rather than degrading it. Contradictory, Lu *et al.* (2020) state that implementing Carroll's pyramid helps the companies rate their effectiveness related to each of the CSR dimensions. The pyramid of Carroll gives four responsibilities to be followed by a company such as "to obey law, to have philanthropic causes, to be economically profitable and to be ethically responsible". Thus, it provides the aspects in which the companies would have a more positive influence on recognising their philanthropic activities as a part of CSR. Figure 8 shows four areas of responsibilities which would enhance their part in the market competition level. As outlined by Kusyk, (2021), the current mental state of having more concentration on ethics of companies by customers and other stakeholders, proper evaluation of CSR implementation is required.



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Proper acknowledgement of ethical behaviour and business integrity goes further than compliance with related laws and regulations. Thus, the inclusion of this theory can help companies to know their position with respect to implementing CSR policies. Contradictorily, Silva Junior *et al.* (2023) state that brand awareness and brand image are the potential mediators in lieu between sustainable, ethical and philanthropic dimensions. Thus, it can be assumed that there is a positive influence on the performance of an organization of these three dimensions. As stated by Brin & Nehme, (2019), the use of the Carroll pyramid in the CSR activities process helps the business to drive success fluctuation in examining how responsible they are in these four areas. Thus, maintaining its CSR standards with the help of the Carroll pyramid would support them in competitive advantages and developing stakeholder's trust which in turn raise brand reputation and its awareness.

METHODOLOGY

Research Design

The study has taken descriptive design to have proper observation of data without manipulating the variables. As stated by Siedlecki, (2020), the use of descriptive data gives a systematic data collection phenomenon by taking aspects of the situation. The use of the positivism philosophy has been considered to have a more logical inquiry with observation to understand the impact of CSR in developing market brand image. Further, the inclusion of the Deductive approach has helped to develop the hypothesis in the first place and then data collection has proceeded to have more consideration of empirical studies.

Data Collection Method

The Primary Quantitative method has been approached in this study to have a proper evaluation of statistics and with the actual experience of participants. As commented by Watkins, (2021), the use of statistics supports to collection of practical responses which include their actual experience. The survey has been conducted with a total of 57 participants which include employees and junior managers of random companies selected. The use of Google form is done through mail and inclusion of 13 questions divided into 3 demographic and 10 variables-related questions. The participant's selection was done by keeping the impact of CSR into consideration and further they have proper knowledge of market brands. Moreover, the survey uses the Likert Scale in the survey as it helps the participant to give their feedback more easily.

Data Analysis

The Excel sheets consisting of the responses of the participants are further inserted in SPSS, a statistical software. As stated by Morgan *et al.* (2019), SPSS usage helps to know the results of big data in statistical form in less time and with more accuracy. The hypothesis's existence is checked by running the regression test on all the variables. Correlation tests that help to evaluate variables' independence are also run in this software. Moreover, tests such as Descriptive and Demographic tests were also done to know the participants' and variables' statistics.

Ethical Consideration

"Data Protection Act, 2018" and related standards have been followed while developing the findings and processing with data collection methods. All the participants filled out the consent form sent and further no questions were used which harmed their privacy. The data collected have been secured in a safety vault for good protection.

Findings and analysis

Understanding the population and the categories to which it belongs is aided by demographic analysis. This has been done to learn about their perspectives based on their categories and experiences based therein. The three criteria listed below are used to break apart the participants for additional statistical analysis.



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Understanding the effects of factors and how the male and female categories use them is made easier with the aid of gender analysis. Table 1 displays the appropriate frequency at which the responses are provided; the number 31 indicates that males make up the majority. However, the incidence level of female opinions is 23, while that of other viewpoints is 8. The gender distribution of the population is depicted in Figure 5, with males accounting for most of the population (54.4 cumulative percentage). Nonetheless, women account for a substantial amount (40.4 %).

Age Group

Table 2 delineates the demographic into four cohorts ranging in age from 25 to 55 and beyond, enabling the study to comprehend that a diverse range of individuals participates in the financial markets. The age range of 40 to 55 years old accounts for most of the frequency, with a value of 15. Figure 6 displays the population distribution by age group, with 31-40 years accounting for most of the population (78.9 cumulative percentage). However, the age group of 45 to 55, with 19.3% takes a valid percentage.

Working Status

This descriptive test looks at the data entered the statistical tool and aids in analyzing the central tendency of the value of the entire variable with dispersion (Murphy *et al.* 2021). The major goal of this test is to summaries data into metrics, as shown in the table below. Figure 7 displays the population distribution by working professional group, with 4 categories accounting for most of the population (78.9 cumulative percentages). However, the working group of data analyst, with 15.79% takes a valid percentage. Finance analysts occupied 33.33% of overall population.

Statistical Analysis**Descriptive Analysis**

This descriptive test looks at the data entered the statistical tool and aids in analyzing the central tendency of the value of the entire variable with dispersion (Murphy *et al.* 2021). The major goal of this test is to summaries data into metrics, as shown in the table below. The four different categories of descriptive measurements and their metrics, which take four independent and one dependent value into account, are described in Table 4. Four different measurements or types can be identified: variance, which includes skewness and kurtosis values; central tendency, which includes mean, mode, and median; variance, which includes standard deviation and variance; and standard error, which includes skewness and kurtosis values (Talpada *et al.* 2019). The standard error shows the mean and its data dispersion and aids in reflecting the likelihood of ambiguity. With a comparable rate of uncertainty chances, the financial stability or viability DV has the second biggest standard error value. In descriptive statistics, the skewness test quantifies the degree of asymmetry in a likely distribution and can be classified as positive or negative, with standard deviations of 0.5 to 1 and -1 to -0.5, respectively. Except for IV2, all other variables in the above table have negative skewness values. Kurtosis is a statistic that is used to quantitatively influence a probability curve. The correlation test values are displayed in Table 5 to help illustrate the degree of influence that each variable has on the others. With the use of the Pearson and Spearman tests, the correlation test is a statistical technique that aids in determining correlations between the variables (Herath *et al.* 2019). The covariance of the variables is displayed by this Pearson coefficient, which is then divided by the standard deviation products. When a relationship is positive or direct, the standard or idle value of Pearson should be near 1, and when it is negative, it should be close to -1. *et al.*, Gao 2022). No variable in the above table can have a negative relationship, but there can be a weak relationship. The table shows that there is no negative correlation between any of the variables, however, there is a weak correlation (Pearson value of 0.257 and sig value of 0.063) between financial stability and inclinations for equities trading. Furthermore, a significant correlation between investment selections and financial sustainability is indicated by Pearson's value of 0.686.

Hypothesis Testing Analysis**Hypothesis 1**

The three metrics of regression analysis—model summary, ANOVA, and coefficients—are displayed in Table 7. The acquired value of R is .872 and regression analysis provides values that indicate the degree to which the





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corresponding independent variables have an impact on the dependent variables (Makowski *et al.* 2020). R-square, sig value, and adjusted square value are displayed in the above table at 0.066 and 0.048, respectively, indicating that 4.8% of the independent variables in this instance. Given that the significance value is smaller than 0.05, or 0.000, there is a positive hypothesis test in this instance. As the value of significance is lower than .05, from this analysis, it can be stated that the alternative hypothesis is supported.

Hypothesis 2

The three metrics of regression analysis—model summary, ANOVA, and coefficients—are displayed in Table 7. The table indicates that one dependent variable makes up about 34% of the independent variables in this instance of equities trading preference, with R-square, sig value, and adjusted square values of 0.000 and 0.648, respectively. Given that the significance value is smaller than 0.05, or 0.000, there is a positive hypothesis test in this instance. The acquired value of R is .805. As the value of significance is lower than .05, from this analysis, it can be stated that the alternative hypothesis is supported.

Hypothesis 3

The acquired value of R from the analysis is .811 and the value of R square is .658. The three metrics of regression analysis model summary, ANOVA, and coefficients are displayed in Table 6. R-square and sig values are displayed in the above table as 0.686, and 0.000 respectively. As the sig, this situation has a positive hypothesis test. The value is 0.000, or less than 0.05. As the value of significance is lower than .05, from this analysis, it can be stated that the alternative hypothesis is supported.

Hypothesis 4

The acquired value of R from the analysis is .826 and the value of R square is .658. The three metrics of regression analysis model summary, ANOVA, and coefficients are displayed in Table 6. R-square and sig values are displayed in the above table as 0.686, and 0.000 respectively. As the sig, this situation has a positive hypothesis test. The value is 0.000, or less than 0.05. As the value of significance is lower than .05, from this analysis, it can be stated that the alternative hypothesis is supported.

DISCUSSIONS

To ensure that the financial position is stable, a variety of financial criteria are used. The term "finance" encompasses a wide range of concepts, and making judgements or engaging in trade requires a thorough understanding of the subject (Maulud & Abdulazeez, 2020). This study incorporates equity along with other kinds of assets when examining investments in finance-related assets. In the process of financial transactions, the middleman is the financial intermediary. The survey's results from participants who work in the financial industry were used to help conduct the tests. Four key components of financial markets are necessary to assist in making long-term investing decisions. Every financial decision has a risk and probability component associated with it, as well as other financial words. Therefore, it is crucial to include discounting elements that consider risks, and conducting thorough market research is necessary to address this successfully. In financial marketplaces like the stock market, where demand ultimately determines price, the incorporation of trade preferences like equity is crucial. Although equity carries significant risks, it also yields significant returns because of market fluctuations and dividend adherence (Ahmed *et al.*, 2021). With a Pearson value of 0.686 and a sig value of, Table 5's correlation test demonstrates a robust relationship between financial security and investment decisions. Considering a Pearson reading of 0.559 and a sig value of 0.000, it is even evident that there is a positive correlation between financial assets like equity and the function of financial intermediaries. As a result, it can be inferred that all the factors are always related to one another and that maintaining a profitable and active trading position requires regular, in-depth study and appropriate understanding. Table 6, on the other hand, demonstrates the poor relationship or impact of the preference for equities trading on financial stability, with a sig value of 0.063—less than 0.005 and perhaps near the null hypothesis value. This helps the research comprehend that there are a variety of additional metrics that can support financial





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stability if the equity value is not increasing at the appropriate rate. There are many ramifications for this research because it is highly significant in several areas, such as economics, establishing policies, and personal finance. First off, it gives investors themselves direct empowerment (Radović-Marković & Živanović, 2019). A significant portion of people in today's complex financial climate struggle with making investment selections since they do not know enough about the subject. This research serves as a reference, providing insight into the options for investing in financial real estate and choosing intermediaries, empowering investors to make knowledgeable decisions.

CONCLUSIONS

Consequently, using a variety of financial measurements and factors is necessary to preserve financial stability even while making long-term decisions. When used as a trading tool in the financial market, equity is preferred because, with careful study, it can yield higher profits. Furthermore, using the market's regular upgrades is necessary when choosing investments and interacting with financial intermediaries. As a result, the literature review's description provides accurate information on the financial market, and the application of qualitative approaches aids in addressing the research questions. Additionally, a regression evaluation is used in the outcomes and discussion section to assess the hypothesis developed to determine the relationship between the direct and indirect variables. This study's primary goal is to find out how much investor knowledge there is about financial assets and how they trade stocks according to their own preferences via financial intermediaries. The aim of this endeavor is to address knowledge and attitude gaps among those who work in the financial industry.

REFERENCES

1. Ahmed, A. A. A., Paruchuri, H., Vadlamudi, S., & Ganapathy, A. (2021). Cryptography in Financial Markets: potential channels for future financial stability. *Academy of Accounting and Financial Studies Journal*, 25(4), 1-9. Retrieved on 19th September 2023 from: <https://search.proquest.com/openview/af54a4bc6f5e19c8e4b399fa3b4fb660/1?pq-origsite=gscholar&cbl=29414>
2. Barauskaite, G., & Streimikiene, D. (2021). Corporate social responsibility and financial performance of companies: The puzzle of concepts, definitions and assessment methods. *Corporate Social Responsibility and Environmental Management*, 28(1), 278-287. Retrieved from <https://onlinelibrary.wiley.com/doi/abs/10.1002/csr.2048> Retrieved on 31st October 2023
3. Brin, P. V., & Nehme, M. N. (2019). Corporate social responsibility: analysis of theories and models. Retrieved from <https://repository.kpi.kharkov.ua/handle/KhPI-Press/50106> Retrieved on 31st October 2023
4. Coca-colacompany 2023, *Purpose & Vision* Available at <https://www.coca-colacompany.com/about-us/purpose-and-vision> [Accessed on 31st October 2023]
5. D'Avanzo, E., Franch, M., & Borgonovi, E. (2021). Ethics and Sustainable Management. An empirical modelling of Carroll's pyramid for the Italian landscape. *Sustainability*, 13(21), 12057. Retrieved from <https://www.mdpi.com/2071-1050/13/21/12057> Retrieved on 31st October 2023
6. Dmytriyev, S. D., Freeman, R. E., & Hörisch, J. (2021). The relationship between stakeholder theory and corporate social responsibility: *Differences, similarities, and implications for social issues in management*. *Journal of Management Studies*, 58(6), 1441-1470. Retrieved from <https://onlinelibrary.wiley.com/doi/abs/10.1111/joms.12684> Retrieved on 31st October 2023.
7. Hanlon, A., 2020. Ethics in digital marketing and social media. *The SAGE Handbook of Marketing Ethics*, p.424. Retrieved from <https://www.torrossa.com/gs/resourceProxy?an=5018760&publisher=FZ7200#page=442> Retrieved on 31st October 2023.
8. Hassan Al-Tamimi, H. A. (2018). *Corporate social responsibility practices of UAE banks*. *Global Journal of Business Research*, 8(3), 91-108. Retrieved from https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2451207 Retrieved on 31st October 2023.





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9. Islam, T., Islam, R., Pitafi, A. H., Xiaobei, L., Rehmani, M., Irfan, M., & Mubarak, M. S. (2021). The impact of corporate social responsibility on customer loyalty: The mediating role of corporate reputation, customer satisfaction, and trust. *Sustainable Production and Consumption*, 25, 123-135. Retrieved from <https://www.sciencedirect.com/science/article/pii/S2352550919304944> Retrieved on 31st October 2023
10. Kusyk, S. (2021). Carroll's CSR Pyramid: An Empirical Investigation of SME CSR Orientation. *Journal of Leadership, Accountability and Ethics*, 18(4), 100-115. Retrieved from <https://search.proquest.com/openview/7ce480f77892fbc4e00e80a0d31a8b36/1?pq-origsite=gscholar&cbl=39006> Retrieved on 31st October 2023
11. LACAP, J. P. G., CHAM, T. H., & LIM, X. J. (2021). The Influence of Corporate Social Responsibility on Brand Loyalty and The Mediating Effects of Brand Satisfaction and Perceived Quality. *International Journal of Economics & Management*, 15(1). Retrieved from https://www.researchgate.net/profile/Tat-Huei-Cham-2/publication/350739563_The_Influence_of_Corporate_Social_Responsibility_on_Brand_Loyalty_and_The_Mediating_Effects_of_Brand_Satisfaction_and_Perceived_Quality/links/64469da9017bc07902d765af/The-Influence-of-Corporate-Social-Responsibility-on-Brand-Loyalty-and-The-Mediating-Effects-of-Brand-Satisfaction-and-Perceived-Quality.pdf Retrieved on 31st October 2023
12. Ledecy, M., 2023, *Corporate Social Responsibility: Past, Present, And Future* Available at <https://everfi.com/blog/community-engagement/csr-history/#:~:text=Today%2C%20CSR%20is%20a%20big,%2C%20education%2C%20and%20the%20environment.> [Accessed on 31st October 2023]
13. Lu, J., Ren, L., Zhang, C., Rong, D., Ahmed, R. R., & Streimikis, J. (2020). Modified Carroll's pyramid of corporate social responsibility to enhance organizational performance of SMEs industry. *Journal of Cleaner Production*, 271, 122456. Retrieved from <https://www.sciencedirect.com/science/article/pii/S0959652620325038> Retrieved on 31st October 2023
14. Marino, S., 2023 165 *Strategy-Changing Digital Marketing Statistics for 2023* Available at <https://www.wordstream.com/blog/ws/2022/04/19/digital-marketing-statistics> [Accessed on 31st October 2023]
15. Maulud, D., & Abdulazeez, A. M. (2020). A review on linear regression comprehensive in machine learning. *Journal of Applied Science and Technology Trends*, 1(4), 140-147. Retrieved on 19th September 2023 from: <https://jastt.org/index.php/jasttpath/article/view/57>
16. Mawarni, I., & Muzammil, O. M. (2023). The Influence of Corporate Social Responsibility, Social Media Marketing, Sales Promotion, and Perceived Value on Consumer Purchase Decision on the Tokopedia Marketplace. *Dinasti International Journal of Management Science*, 4(4), 760-768. Retrieved from <https://dinastipub.org/DIJMS/article/view/1765> Retrieved on 31st October 2023.
17. Menghwar, P. S., & Daood, A. (2021). Creating shared value: A systematic review, synthesis and integrative perspective. *International Journal of Management Reviews*, 23(4), 466-485. Retrieved from <https://onlinelibrary.wiley.com/doi/abs/10.1111/ijmr.12252> Retrieved on 31st October 2023
18. Morgan, G. A., Barrett, K. C., Leech, N. L., & Gloeckner, G. W. (2019). *IBM SPSS for introductory statistics: Use and interpretation*. Routledge. Retrieved from <https://books.google.co.in/books?hl=en&lr=&id=TvYTEAAAQBAJ&oi=fnd&pg=PP1&dq=SPSS+importance+in+research+methodology&ots=dYGSnLYyqa&sig=dnwYEG96-g03dudqcERn383GnXw> Retrieved on 31st October 2023
19. Nave, A., & Ferreira, J. (2019). Corporate social responsibility strategies: Past research and future challenges. *Corporate Social Responsibility and Environmental Management*, 26(4), 885-901. Retrieved from <https://onlinelibrary.wiley.com/doi/abs/10.1002/csr.1729> Retrieved on 31st October 2023
20. Ncbi.nlm.nih.gov 2023, *Factors Affecting the Implementation of Corporate Social Responsibility in the Health Technology Industry in Greece* Available at <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10319453/> [Accessed on 31st October 2023]
21. Pucheta-Martínez, M. C., & Gallego-Álvarez, I. (2019). An international approach of the relationship between board attributes and the disclosure of corporate social responsibility issues. *Corporate Social Responsibility and Environmental Management*, 26(3), 612-627. Retrieved from <https://onlinelibrary.wiley.com/doi/abs/10.1002/csr.1707> Retrieved on 31st October 2023.





Ramesha et al.,

22. Radović-Marković, M., & Živanović, B. (2019). Fostering green entrepreneurship and women's empowerment through education and banks' investments in tourism: Evidence from Serbia. *Sustainability*, 11(23), 6826. <https://www.mdpi.com/2071-1050/11/23/6826>
23. Sharma, R., & Jain, V. (2019). CSR, trust, brand loyalty and brand equity: empirical evidences from sportswear industry in the NCR region of India. *Metamorphosis*, 18(1), 57-67. Retrieved from <https://journals.sagepub.com/doi/abs/10.1177/0972622519853158> Retrieved on 31st October 2023
24. Siedlecki, S. L. (2020). Understanding descriptive research designs and methods. *Clinical Nurse Specialist*, 34(1), 8-12. Retrieved from https://journals.lww.com/cns-journal/Fulltext/2020/01000/Understanding_Descriptive_Research_Designs_and.4.aspx Retrieved on 31st October 2023
25. Silva Junior, A. D., Martins-Silva, P. D. O., Coelho, V. D., & Sousa, A. F. D. (2023). The corporate social responsibility pyramid: its evolution and the proposal of the spinner, a theoretical refinement. *Social Responsibility Journal*, 19(2), 358-376. Retrieved from <https://www.emerald.com/insight/content/doi/10.1108/SRJ-05-2021-0180/full/html> Retrieved on 31st October 2023
26. Singh, K., & Misra, M. (2021). Linking corporate social responsibility (CSR) and organizational performance: The moderating effect of corporate reputation. *European Research on Management and Business Economics*, 27(1), 100139. Retrieved from <https://www.sciencedirect.com/science/article/pii/S244488342030320X> Retrieved on 31st October 2023
27. Statista 2021, Available at <https://www.statista.com/statistics/818754/global-marketing-data-market-size/> [Accessed on 31st October 2023]
28. Štreimikienė, D., & Ahmed, R. R. (2021). Corporate social responsibility and brand management: Evidence from Carroll's pyramid and triple bottom line approaches. *Technological and Economic Development of Economy*, 27(4), 852-875. Retrieved from <https://jau.vgtu.lt/index.php/TEDE/article/view/14520> Retrieved on 31st October 2023
29. Tiep Le, T., Ngo, H. Q., & Aureliano-Silva, L. (2023). Contribution of corporate social responsibility on SMEs' performance in an emerging market—the mediating roles of brand trust and brand loyalty. *International Journal of Emerging Markets*, 18(8), 1868-1891. Retrieved from <https://www.emerald.com/insight/content/doi/10.1108/IJOEM-12-2020-1516/full/html> Retrieved on 31st October 2023
30. Unctad.org 2022, *Global trade hits record high of \$28.5 trillion in 2021, but likely to be subdued in 2022* Available at <https://unctad.org/news/global-trade-hits-record-high-285-trillion-2021-likely-be-subdued-2022> [Accessed on 31st October 2023]
31. Unido.org 2023, CSR Definition Available at <https://www.unido.org/our-focus/advancing-economic-competitiveness/competitive-trade-capacities-and-corporate-responsibility/corporate-social-responsibility-market-integration/what-csr#:~:text=Corporate%20Social%20Responsibility%20is%20a,and%20interactions%20with%20their%20stakeholders.> [Accessed on 31st October 2023]
32. Wang, S., Liao, Y. K., Wu, W. Y., & Le, K. B. H. (2021). The role of corporate social responsibility perceptions in brand equity, brand credibility, brand reputation, and purchase intentions. *Sustainability*, 13(21), 11975. Retrieved from <https://www.mdpi.com/2071-1050/13/21/11975> Retrieved on 31st October 2023
33. Watkins, M. W. (2021). *A step-by-step guide to exploratory factor analysis with SPSS*. Routledge. Retrieved from https://books.google.co.in/books?hl=en&lr=&id=BaEsEAAAQBAJ&oi=fnd&pg=PP11&dq=SPSS+importance+in+research+methodology&ots=um7d7rESx8&sig=gMSt2NhYp30FObIY5bDInOuo_gQ Retrieved on 31st October 2023
34. Widyastuti, S., Said, M., Siswono, S., & Firmansyah, D. A. (2019). Customer trust through green corporate image, green marketing strategy, and social responsibility: A case study. Retrieved from <https://www.um.edu.my/library/oar/handle/123456789/43004> Retrieved on 31st October 2023
35. Yuan, Y., Lu, L. Y., Tian, G., & Yu, Y. (2020). Business strategy and corporate social responsibility. *Journal of Business Ethics*, 162, 359-377. Retrieved from <https://link.springer.com/article/10.1007/s10551-018-3952-9> Retrieved on 31st October 2023





Ramesha et al.,

36. Zu, L. (2022). Doing Business with Compassion: Social Responsibility. In *Responsible and Sustainable Business: The Taoism’s Perspective* (pp. 99-120). Cham: Springer International Publishing. Retrieved from https://link.springer.com/chapter/10.1007/978-3-030-91117-1_10 Retrieved on 31st October 2023.

Table 1: Gender (Source: SPSS)

Q2: What is your gender?					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Female	23	40.4	40.4	40.4
	Male	31	54.4	54.4	94.7
	Prefer not to say	3	5.3	5.3	100.0
	Total	57	100.0	100.0	

Table 2: Age Group (Source: SPSS)

Q3: What is your age?					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Above 50 years	4	7.0	7.0	7.0
	Between 23-30 years	14	24.6	24.6	31.6
	Between 31-40 years	20	35.1	35.1	66.7
	Between 40-50 years	15	26.3	26.3	93.0
	Prefer not to say	4	7.0	7.0	100.0
	Total	57	100.0	100.0	

Table 3: Working Profession (Source: SPSS)

Q4: What is your profession?					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Data Analyst	9	15.8	15.8	15.8
	Finance Analyst	19	33.3	33.3	49.1
	HR Analyst	9	15.8	15.8	64.9
	Marketing Analyst	14	24.6	24.6	89.5
	Others	2	3.5	3.5	93.0
	Prefer not to say	4	7.0	7.0	100.0
	Total	57	100.0	100.0	

Table 4: Descriptive Analysis (Source: SPSS)

	Descriptive Statistics											
	N	Range	Minimum	Maximum	Mean		Std. Deviation	Variance	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
DV	57	8.00	2.00	10.00	4.0000	.27306	2.06155	4.250	1.673	.316	2.297	.623
IV1	57	8.00	2.00	10.00	4.1404	.28588	2.15836	4.059	1.391	.316	1.173	.623
IV2	57	8.00	2.00	10.00	4.1579	.28074	2.11955	4.492	1.313	.316	1.056	.623
IV3	57	8.00	2.00	10.00	4.0702	.27858	2.10323	4.424	1.515	.316	1.601	.623
IV4	57	8.00	2.00	10.00	4.0175	.28812	2.17528	4.732	1.595	.316	1.870	.623
Valid N (listwise)	57											





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Table 5: Correlation Test (Source: SPSS)

Correlations						
	DV	IV1	IV2	IV3	IV4	
DV	Pearson Correlation	1	.827**	.805**	.811**	.836**
	Sig. (2-tailed)		.000	.000	.000	.000
	Sum of Squares and Cross-products	238.000	206.000	197.000	197.000	210.000
Covariance		4.250	3.679	3.518	3.518	3.750
	N	57	57	57	57	57
	Pearson Correlation	.827**	1	.830**	.816**	.908**
Sig. (2-tailed)	.000		.000	.000	.000	
IV1	Sum of Squares and Cross-products	206.000	260.877	212.737	207.439	238.860
	Covariance	3.679	4.659	3.799	3.704	4.265
	N	57	57	57	57	57
IV2	Sum of Squares and Cross-products	197.000	212.737	251.579	203.368	214.842
	Covariance	3.518	3.799	4.492	3.632	3.836
	N	57	57	57	57	57
IV3	Sum of Squares and Cross-products	197.000	207.439	203.368	247.719	195.930
	Covariance	3.518	3.704	3.632	4.424	3.499
	N	57	57	57	57	57
IV4	Sum of Squares and Cross-products	210.000	238.860	214.842	195.930	264.982
	Covariance	3.750	4.265	3.836	3.499	4.732
	N	57	57	57	57	57

** . Correlation is significant at the 0.01 level (2-tailed).

Table 6: Hypothesis testing (Source: SPSS)

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	.827 ^a	.683	.678	1.17034	.683	118.761	1	55	.000	2.102

a. Predictors: (Constant), IV1
b. Dependent Variable: DV

Table 7: Hypothesis testing (Source: SPSS)

ANOVA ^a						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	162.667	1	162.667	118.761	.000 ^b
	Residual	75.333	55	1.370		
	Total	238.000	56			

a. Dependent Variable: DV
b. Predictors: (Constant), IV1

Coefficients ^a											
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations			Collinearity Statistics	
		B	Std. Error	Beta			Zero-order	Partial	Part	Tolerance	VIF
1	(Constant)	.731	.338		2.164	.035					
	IV1	.790	.072	.827	10.898	.000	.827	.827	.827	1.000	1.000

a. Dependent Variable: DV





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Table 8: Hypothesis testing (Source: SPSS)

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	.805 ^a	.648	.642	1.23390	.648	101.320	1	55	.000	1.647

a. Predictors: (Constant), IV2
 b. Dependent Variable: DV

Table 9: Hypothesis testing (Source: SPSS)

ANOVA^a

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	154.262	1	154.262	101.320	.000 ^b
	Residual	83.738	55	1.523		
	Total	238.000	56			

a. Dependent Variable: DV
 b. Predictors: (Constant), IV2

Coefficients^a

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations			Collinearity Statistics	
		B	Std. Error	Beta			Zero-order	Partial	Part	Tolerance	VIF
1	(Constant)	.744	.362		2.053	.045					
	IV2	.783	.078	.805	10.066	.000	.805	.805	.805	1.000	1.000

a. Dependent Variable: DV

Table 10: Hypothesis testing (Source: SPSS)

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	.811 ^a	.658	.652	1.21606	.658	105.940	1	55	.000	1.463

a. Predictors: (Constant), IV3
 b. Dependent Variable: DV

Table 11: Hypothesis testing (Source: SPSS)

ANOVA^a

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	156.665	1	156.665	105.940	.000 ^b
	Residual	81.335	55	1.479		
	Total	238.000	56			

a. Dependent Variable: DV
 b. Predictors: (Constant), IV3

Coefficients^a

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations			Collinearity Statistics	
		B	Std. Error	Beta			Zero-order	Partial	Part	Tolerance	VIF
1	(Constant)	.763	.353		2.160	.035					
	IV3	.795	.077	.811	10.293	.000	.811	.811	.811	1.000	1.000

a. Dependent Variable: DV





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Table 12: Hypothesis testing (Source: SPSS)

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	.836 ^a	.699	.694	1.14076	.699	127.888	1	55	.000	1.895

a. Predictors: (Constant), IV4
 b. Dependent Variable: DV

Table 13: Hypothesis testing (Source: SPSS)

ANOVA^a

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	166.426	1	166.426	127.888	.000 ^b
	Residual	71.574	55	1.301		
	Total	238.000	56			

a. Dependent Variable: DV
 b. Predictors: (Constant), IV4

Coefficients^a

Model		Unstandardized Coefficients		Standardized Coefficients			Correlations			Collinearity Statistics	
		B	Std. Error	Beta	1	Sig.	Zero-order	Partial	Part	Tolerance	VIF
1	(Constant)	.816	.320		1	.013					
	IV4	.793	.070	.836	11.309	.000	.836	.836	.836	1.000	1.000

a. Dependent Variable: DV

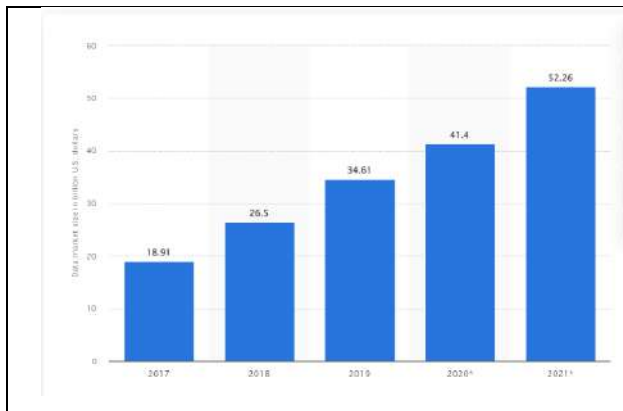


Figure 1: Increased Marketing size at the global level (Source: Statista, 2021)

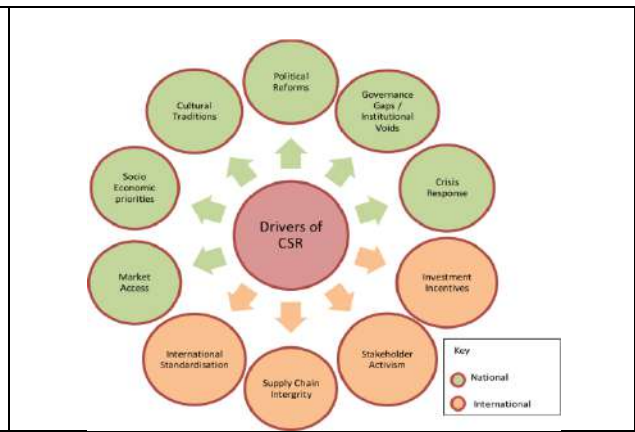


Figure 2: CSR drivers showing the relationship for corporate sustainability (Source: Influenced by Barauskaite & Streimikiene, 2021)



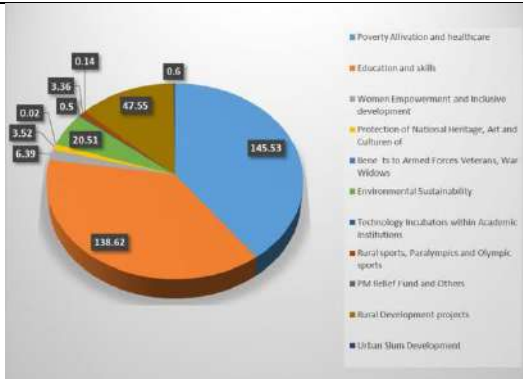


Figure 3: Global demand for CSR related to various projects (Source: Jain, 2017)

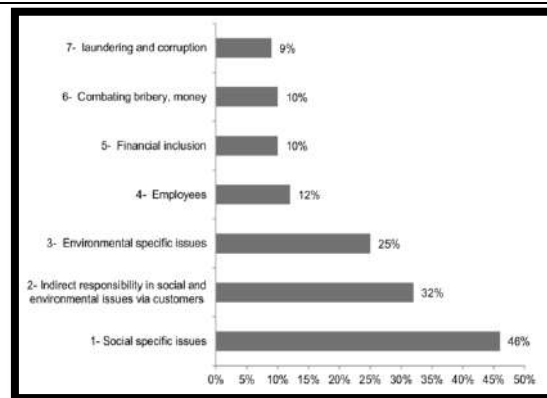


Figure 4: Issues faced by businesses related to CSR in various areas (Source: Hassan Al-Tamimi, 2018)



Figure 5: Factors creating difficulty in implementing CSR (Source: Influenced by Dmytriyeu, Freeman & Hörisch, 2021)

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Figure 6: Process of marketing by taking Social responsibility as a crucial factor (Source: Influenced by Mawarni & Muzammil, 2023)





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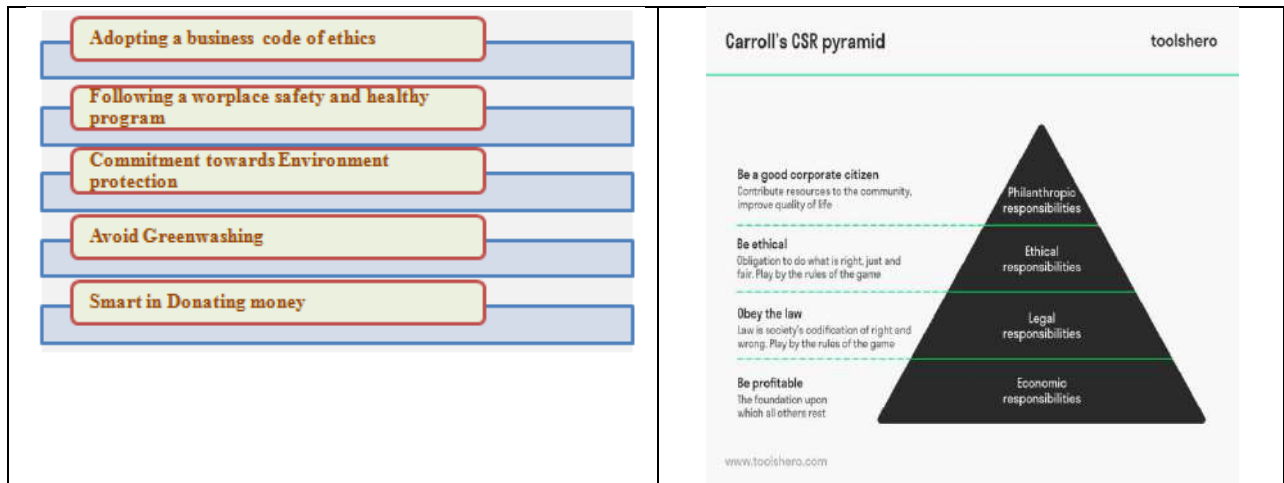


Figure 7: Strategies in implementing CSR activities to develop market brand (Source: Influenced by Zu, 2022)



Figure 8: Carroll's pyramid in identifying four important responsibilities (Source: Influenced by Štreimikienė& Ahmed, 2021)

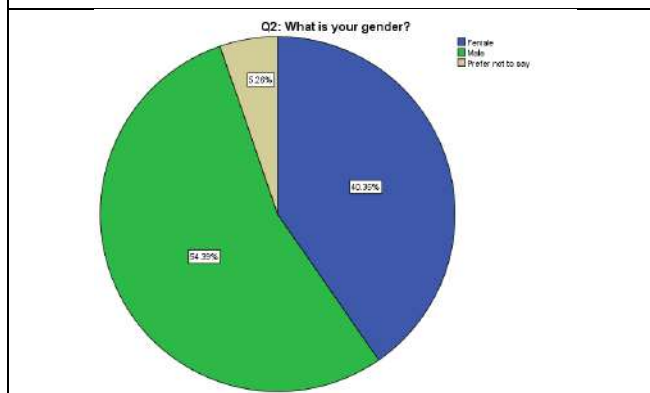


Figure 9: Gender (Source: SPSS)

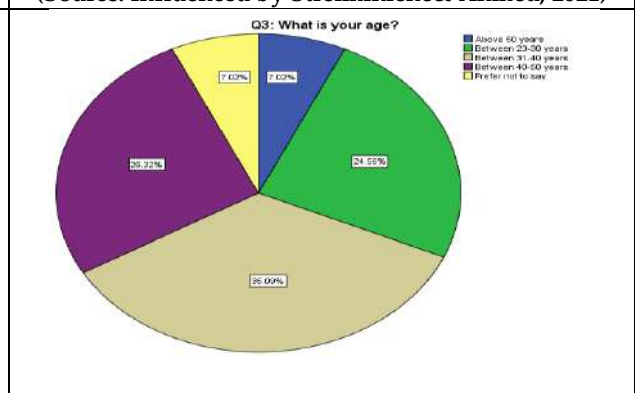


Figure 10: Age Group (Source: SPSS)

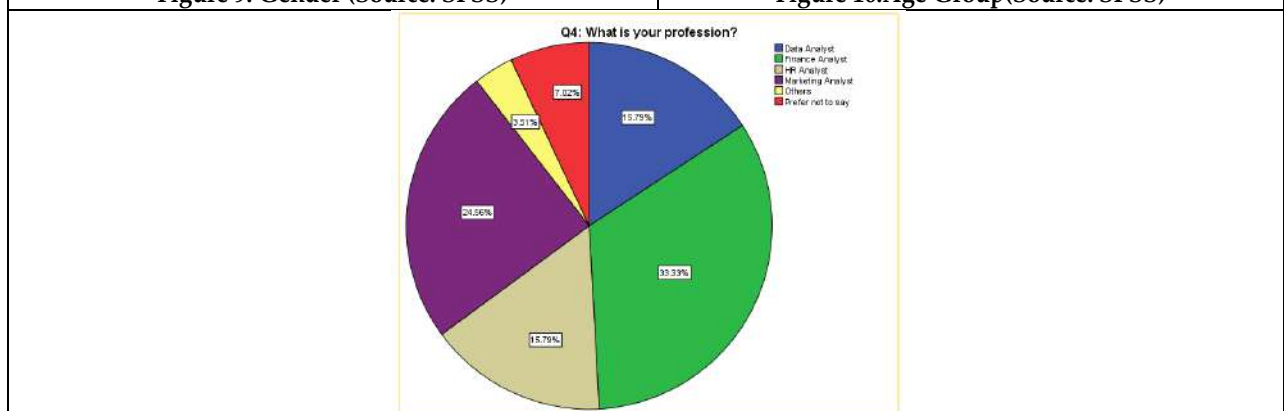


Figure 11: Working Profession (Source: SPSS)





Trampled Psyche of Women: Embodying the Patriarchal Framework in Easterine Kire's A Terrible Matriarchy

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ABSTRACT

Women encounter multiple issues of discrimination, subjugation, harassment and restrictions in every phase of life. Hierarchy pertaining to supremacy and authority force women to face subordination and violence. The unbiased status of women occurs due to the disadvantageous position of women compounded by illiteracy, intense suppression, poverty and despair. The Angami, one of the tribes of Nagaland, a State in the Northeast part of India, subjugates womenfolk and deny recognition. The tribal patriarchal sovereignty hinders the accessibility and the emancipation of women. The article highlights the trampled and the packed down psyche of women in Easterine Kire's *A Terrible Matriarchy* (2007). Patriarchy designs, determines and demonstrates the role of women in the community as well as in the family. It is the vilest expression employed by men to victimize women. Male-centric norms have endowed men with authority, privilege, and opportunity to exploit women. Choices are restricted to women whereas men relishes ample opportunities. Fortunately or unfortunately, male-heir inherits the legacy whereas female-heir is forfeited. Education for women is a tussle in the prejudiced-society. The perpetual negligence and persecution diminishes the individuality of women both internally and externally.

Keywords: Stereotyping, Submissiveness, Property, Education and Individuality

INTRODUCTION

Feminism is a compilation of various movements that attempt to define, establish and to defend equal political, economic, and social rights and equal opportunities for women. It also includes the status that societies prefer the



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male viewpoint and that women are treated secondary within those societies. Feminist theory is the expansion of feminism movements into theoretical, fictional, or philosophical discussion. The aim of the theory is to find out the nature of gender inequality in the world. Madsen declares, “. . .feminism deals with women and their status in society and asks questions about oppression, consciousness and gender. . . .” (200). Feminist theory focuses on the themes such as discrimination, objectification, oppression, patriarchy, stereotyping, art and aesthetics. The theory also scrutinizes women's and men's social roles, experiences, interests, chores, and feminist politics in different disciplines.

In the world, gender dichotomy is ubiquitous in all aspects of life. Irrespective of class, clan, community, creed and country, women endure diversified hardships in the hands of men. Right from the birth, women are made to experience trials and tribulations in life till their death. Gender becomes a license for men to interiorize women. The deleterious effect of gender discrimination has pushed many to trauma. Biasness endures from generation and becomes purely irrefutable evidence. Generally, a society is built upon patriarchy where matriarchy is of little power. Patriarchy gives significance and recognition only to men whereas it puts women in the trivial position. Patriarchal system curtails the freedom of women and pushes them to the edges of the society. Most of the tribal communities reside in the Northeast part of India. In particular, the Angami tribe dwells in the state of Nagaland. The culture of the Angami tribe is rested upon patriarchy and the social status of women is in a pathetic situation. The power structure is centred on men and the power of women is crippled by the system. Hence, discrimination becomes a part of daily routine in the life of women in the Angami tribe.

Easterine Kire is a Nagaland writer who writes for the welfare of her own community. She belongs to the Angami tribe and her works portray the screened sufferings of the tribe. Kire is very particular about the woes of women and she deals with the issues of women in the Angami tribe. Her novel, *A Terrible Matriarchy* (2007), centres around the life of a young girl named, Dilieno. Dilieno is a victim of the patriarchal structure of the Angami tribe. Through the eyes of the protagonist, the novelist illustrates the iron-teeth clutches of patriarchy in the tribe. The article is an attempt to focus how far patriarchy stretches itself to stereotype and subordinate women to keep them under its control. It highlights the incidents where the rights of womenfolk are curbed. It also discusses the remissness of the society towards women leads to the loss of their individuality.

Gender stereotype is prevalent in the present society all over the world. Stereotype is a fixed opinion or notion about the character or the individuality of a particular person. However, it is also a misconception because it is a preconceived one. In the case of gender stereotype, women are negatively stereotyped about their role and function in the society but men are less stereotyped and that too positively. The patriarchal system has created the gender stereotype that favours men. Castillo-Mayén and Montes-Berges assert, “. . .gender stereotypes entail important negative consequences. . .these consequences have a higher impact on women, which in addition favours their vulnerability as victims of violence against them. . . .” (1044). Men misuse the vulnerability of women to label them as such. They regard women as fragile and cannot perform the activities as same as men. With this notion, women are not allowed to take active part in the societal activities and are expected to remain behind the bars. The confinement kills the creative and the innovative potentials of women.

In the Angami tribe, the lives of women are stereotyped and are expected to execute the tasks exclusively assigned for them. The patriarchal structure of the community wants to paralyze the function of women within four walls. The protagonist of the novel Dilieno is curious to know the role of women in the Angami society. She grows up seeing the sufferings of the womenfolk in the society. Even at the young age, she wants to find out the responsibilities of women and enquires another character named, Bano. Dilieno is grief-stricken when she comes to know about the sad condition of women. To her questions, Bano replies, “. . .Their mission in life is to marry and have children and be able to cook and weave cloths and look after the household. . . .” (24). The women of Angami tribe is chained with their household duties as house performs a dominant part in their life. The patriarchal system neglects the other wishes of women and locks them inside a building.



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Submissiveness is an action to subdue a person who is in the subordinate position. The people with higher position always enforce their power on the inferiors and try to suppress them. Submissiveness is also a sort of slavery as the underlings have to obey the commands of the superiors. The patriarchal system of the society forces women to be passive before men. It actually represses the voices of women. Women are silenced as men are regarded as all powerful. Saikia comments, "In the patriarchal structure, the man always exercises authority over the wife. . ." (26). Men enjoy the privileges of patriarchy whereas women suffer. The authority is bestowed on men and women have to go in accordance with them. In a family, men are the final decision makers and women are expected to abide with their wishes. Women cannot make any choice without the consent or consultation with their husbands. Even if they try to make any suggestions, their ideas are shunned just because they are subordinates. Women have to be quiet in all matters.

In a patriarchal society, no due respect is provided to women. The voice of men has more intensity than the voice of women. Views of women are always neglected because men believe that it is the bound duty of women to adhere men. In the novel, the subordination of women in the Angami tribe is explicated through the conversation of Dilieno's parents. Dilieno's paternal grandmother is in her old age and she wants Dilieno to be with her to assist in petty business. Dilieno's mother dislikes the idea because Dilieno is too young to carry out household duties. On the other hand, Dilieno's father wishes to send his daughter with his mother. During the conversation, though Dilieno's mother dissuades the father, he is stubborn to change his mind and stresses, ". . . She will leave tomorrow for Mother's house and I don't want to hear anymore arguments about this" (10). The incident is a witness to the dominance of men over women in the decision-making. Men never want to heed women's advice because they consider that it is a shame for them to listen to the thoughts of women.

An impoverished economic condition is a state when a person lacks sufficient money to lead a respectable life in the society. Lack of money has negative consequences in the life of a human being as it is the root cause of all hardships in life. It also strips a person off from the mainstream society and pushes to the lower-strata. Financial discrimination is one of the injustices women confront. In addition to all the miseries in life, the patriarchal structures of the society make women remain economically backward. The poor economic status continues to subjugate the womenfolk. Roy states, ". . . Uneven balance of wealth and lack of agency have led to the subjugation of women in general. . ." (370). Women are refused to improve their financial status in the society. It affects their daily routine and they endure multiple plights in day-to-day life. The independence of women is vehemently plucked away due to patriarchy. They become defenseless and incapable of breaking the chain of confinement.

Financial exclusion is an invisible war against the liberation of women. Usually, the patriarchal society attempts to repress women. One of the easiest methods is poor economic growth so that men can dominate women without any disturbances. The denial of property to women is vividly picturized in the novel. In one occasion, Dilieno wishes to know the past of her paternal grandmother's past life. Her grandmother's life mirrors the true picture of patriarchy and female persecution. Through the crushed life of grandmother, Dilieno comes to understand the terrible patriarchal system of the Angami tribe. As per the patriarchal norms, after the death of the husband, women tend to lose the property if they do not have a male-heir in the family. Dilieno's mother explains, ". . . In the village, widows without sons lost all their husband's property to other male relatives. . . The understanding was that a woman without a male heir would be given shelter by her in-laws but her daughters could not inherit the father's property. . ." (250). The financial bias on Angami women is ruthless and extreme. The denial of property makes the life of womenfolk worse as they have to carry the entire burden on their shoulders to run the family properly.

Education opens the door to enter into the world and encounter it with boldness and courage. It is one of the basic necessities of all human beings irrespective of gender. Education is a platform for the physical and intellectual development as it induces to think rationally and to move forward in life. Education emancipates people from all barriers. Education for women is still a bane in the patriarchal societies. Illiterate women succumb subjugation and fall as a prey to male-chauvinism. Gouri points out, ". . . Women comprise approximately half of the population in the world. But the hegemonic masculine ideology made them bear a lot as they were denied equivalent



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opportunities. . .education is still not accessible to many. . .” (395-96). Equality is always under question in male-oriented societies. The system curbs the basic rights of the womenfolk. Liberation of women is blocked and women repeatedly have to suffer at the hands of men.

Denial of education to women prevails in the underdeveloped patriarchal societies. It is commonly believed that education to women is futile and it kills the virtue of womenfolk. The privileges are bestowed on men whereas women are destined to live underprivileged. The novel showcases the desire of the protagonist to enter into the academics. Dilieno wishes to get education but her plan is initially refuted because of patriarchy. Her paternal grandmother is one of the victims of the patriarchal system of Angami tribe. When the discussion of Dilieno’s education is taken to the grandmother, she dismisses the proposal. The grandmother expresses her views as, “. . .In our days. . .girls do not go to school. . .I really do not approve of girls getting educated. . .” (22). It is true that most of the women too are corrupted by the norms formulated in the male-dominated societies. The rights of women are ignored and are buried in a pit. Therefore, women live in a world which holds an antagonism against them.

Loss of identity or individuality is a devaluation of the existence of an individual. Identity is a necessity factor for all human beings as it helps to recognize a person’s being in the world. It is an important factor in the society to determine the position of a person. Without an identity, a person is considered as nothing and the particular person is susceptible to misfortunes in life. The identity of women is taken away from them forcefully. The patriarchal society refuses to grant identity to women because it considers women as inconsequential in the society. Yemez opines, “Women are not defined in terms of individuality, but by being associated with men. . . . Defining women through associating them with men causes the exclusion of women as individuals and thus brings about loss of self” (6-7). The individuality of women dwindles as they are often attached with men’s identity. The association with men’s identity detaches women from the society and their existence is omitted. It also results in the loss of their self which hurts them psychologically.

The identity of Angami women has withheld because of the predominant patriarchal pattern in the society. Their individuality is trampled upon and ripped off from them. They are just treated as an asset or a possession of men. The novel delineates the extent of the loss of identity of women through the central character. Dilieno is a very young kid who is inquisitive about the position of women in the Angami tribe. She clarifies all her doubts with another character named, Bano. Bano shows patience to all her questions and responds politely. When Dilieno asks about the identity of women, Bano replies, “. . .girl-children are never considered real members of the family. . . .If they got married, they would always be known as somebody’s wife or somebody’s mother. . .” (24-25). Bano’s answer reveals the true happenings of women in the Angami tribe. Womenfolk are turned down to be considered as the members of the family. The individuality of Angami women is detested and laid waste. As they are treated as objects, their identity is pinned down with the patriarchy.

The article, thus, provides a profound observation on the patriarchal structure of the Angami tribe in Nagaland. The patriarchy crushes the womenfolk of the tribe and refuses to render respect and recognition to women. Women undergo a lot of discriminations throughout their lifetime. Women are stereotyped to a certain circle and their mission in life is determined. Men suppress women in every sphere and women become voiceless before men in making decisions. Denial of property to women is persuasive in the Angami society. Education is hugely excluded for women and they are provided little opportunity to enter into the academics. In addition to this, the identity of women is repudiated and it is connected with men as if women are of no value in the Angami society.

REFERENCES

1. Kire, Easterine. *A Terrible Matriarchy*. Zubaan, 2007.
2. Castillo-Mayén, Rosario and Beatriz Montes-Berges. “Analysis of Current Gender Stereotypes.” *Annals of Psychology*, vol. 30, no. 3, Oct. 2014, pp. 1044-60.





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3. Gouri, K. Vasantha. "Women Education and Empowerment in India with Reference to Telangana and Andhra Pradesh." *Journal of Community Guidance & Research*, vol. 34, no. 2, 2017, pp. 394-414.
4. Madsen, Deborah L. *Feminist Theory and Literary Practice*. Sterling, 2000.
5. Roy, Subhra. "Gender Politics & Discrimination in Post-Colonial Nagaland with Special Reference to Easterine Kire's *A Terrible Matriarchy*." *Language in India*, vol. 15, no. 7, July 2015, pp. 364-73.
6. Saikia, Anjan. "Reflection of the Life of Angami Women in Easterine Kire's *A Terrible Matriarchy*: A Critique." *INTUIT: A Peer Reviewed Multidisciplinary International Research Journal*, vol. 6, 2017, pp. 23-32.
7. Yemez, Öznur. "Loss of Self and the Struggle for Individuality in Kate Chopin's *The Awakening*." *Narrative and Language Studies*, vol. 1, no. 1, Dec. 2013, pp. 1-12.





An Empirical Study on Women Financial Self-Efficacy in Bengaluru Urban District

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ABSTRACT

Financial self-efficacy is a concept which derives the ability of an individual to select decide their own investment pattern consult in their income levels. With emergence of increasing women employment in the country, it is essential for women to also understand and implement the financial decision on her own. Considering the above-mentioned information, paper is coined with a clear-cut objective of understanding the relationship between financial self-efficacy and allied derived factors such as financial attitude, financial attitude is based on the financial knowledge and financial behavior. The boom in the sector of the Information technology and the service industries impetus given by the Government has led to increasing urbanization especially in places like Bengaluru. The data is empirical in nature received through the structured questionnaires collected from women respondents who have income in Bengaluru City through different forms of employment and self-employment. The statistical tool such as Cronbach alpha and Chi-Square test is used to prove the hypothesis

Keywords: Financial Self-Efficacy, Financial Attitude, Financial Knowledge, Financial Behavior.

INTRODUCTION

Financial self-efficacy is the phenomenon to give confidence to the individual to deal with the capacity to manage the finance and achieve the financial goals (Asandimitra, N., &Kautsar, A. 2019). It is driven by the existence of the



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financial knowledge directing towards attitude based on perceptions leading to behavior in financial actions (Ricciardi, V, 2008). The surplus disposable income of individuals after meeting all the expenses leads to savings and investments, the aim of every individual is to maximize the income through their savings and investment (Kaldor, N,1940). The quest for the higher returns is obligated with the requirement of the liquid cash at times of unforeseen exigencies which creates a challenge to the individuals in deciding the duration of the desired savings/investment (De Carvalho, F. J. C, 2015). The present materialistic world demands the minimum standard of living necessitating the commitment expenses every month (Hart, S. L., & Milstein, M. B, 1999), in this challenging era it is essential for every earning individual to obtain minimum skills and knowledge on the financial instrument through which they can act up on their strategies for investment and savings by considering the commitment expenses to be met (Quinn, J. B. et. al 2009).

REVIEW OF LITERATURE

(Dietz, B. E, et.al, 2003). The research was undertaken with a principle of women being unprepared for retirement compared to men, the social economic variables and human capital variables in judging whether the women prefer to go for employer sponsored retirement plans or private retirement plans was chosen as the variables. The studies undertaken with 800 respondents by applying least square regression model and the analysis prove that women prefer to go for private retirement plans and the occupation difference is the main cause for the inference. (Mindra, R., & Moya, M,2017). It is proved in this paper that there is the significant relationship between financial self-efficacy and financial inclusion, there is lot of variation in the demographic factors in utilization of formal financial services. Substantial analysis with 400 respondents by applying structural equation model and regression is used to prove the hypothesis by the researchers. (Heckman. S. J, & Grable J. E, 2011). The research proved with 4,713 participants that more financial knowledge had better financial self-efficacy, significant positive relationship between level of income and personal finance knowledge is proved. Likelihood analysis with variables such as attitude, income and dependency of parents were considered to study financial knowledge and financial Self efficacy. (Tharp, D. T., & Parks-Stamm, E. J. (2021) The researchers conclude that the gender and social context play important role in prediction of financial satisfaction in Taiwan, especially with consideration of personal income, Demographic variables, financial and social support acts along with personality traits of both positivity and negativity is considered under the study with 2713 respondents. Researchers have applied factor analysis to prove their analysis with application of regression model and allied descriptive statistics. The study is undertaken with understanding of the term financial satisfaction based on gender before arriving at the above inferences.

(Boon, T. H, et.al, 2011). The researchers have concluded that gap in the financial knowledge is acting as major constraint in effectively managing the financial affairs. The level of financial awareness among 200 respondents indicates their readiness towards financial planning without dependent on professionals. The 6 variables are analyzed in the study with tax, retirement benefits, estate planning, investment insurance and liability. Chi square test and descriptive statistics is used to prove the data. (Farrell, L, et.al, 2016). The researchers conclude that the women with financial self-efficacy are the prominent holders of the financial products, further the research that women with high financial self-efficacy are most likely to hold investment and saving products compared to debts and credit card dues. The researchers have analyzed using the data from 2,192 respondents applying the regression analysis to draw conclusions. (Rothwell, D. W, et.al, 2016). The authors found the relationship between the financial knowledge, financial self-efficacy and saving outcomes. It is proved that the financial self-efficacy mediates between the financial objective and the savings. The researchers have taken 15,592 respondents into consideration, the demographic analysis and have defined the low-income group at the first level followed by factor analysis with the three structure models were used to prove the analysis. (Ismail. S, et.al, 2017). The researchers conclude that only the financial knowledge have a significance to financial behavior, researchers have applied Cronbach alpha test with regression analysis with 370 respondents as the basis to prove the statement, further the researchers prove that high financial self-efficacy individuals result in achieving a positive financial behavior and are ready to face challenges in financial matters. (Kirsten, C. L,2018). The research prose that there is a significant influence on the training courses



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on finance with financial management skills and Self efficacy, one tailed T-test is used to prove the analysis with 43 respondents. (Asebedo, S. D., & Seay, M. C,2018) The study reveals that there is mediating variable with regard to the financial self-efficacy with the savings attitude of the individuals and the financial knowledge, the step wise factor analysis was conducted to prove the underlying study with data extracted from 1340 respondents. (Asebedo, S. D, et.al,2019). The psychological attributes play an important role in the financial self-efficacy is the result proved by the researchers. The pre retirees are considered for the study as they prepare for retirement, the comparison of the compound traits was overlooked by the basic traits in the analysis and the control is the key factor in finance. The research was undertaken with the regression model with data extracted from 847 respondents. (Gamst-Klaussen, T, et. al,2019). The researches prove that act of delay of financial action operates through the financial self-efficacy component and impacts financial behavior negatively. The second analysis prove that act of delay of financial action and poor financial habits are negatively related to financial planning. Regression analysis is used by the researchers to substantiate conclusion with sample size of 500. (Tahir, M. S, et.al (2020). The researchers conclude that the financial knowledge have relatively lower magnitude of association with financial decision, but have obtained results to prove that financial attitude towards money matters have better association with financial decisions. The research further proves with 8542 respondents' data that people who have the attitude to balance between spending and savings have avoided credit card debt, correlation analysis and descriptive statistics are used as a statistical tool to prove the results. (Hoffmann, A. O., &Plotkina, D,2021). The researchers conclude that people who develop greater financial Efficacy as result of previous experiences display more self-control leading to financial planning tendencies. The researchers have taken experimental method by taking the positive experience a successful previous financial planning vs the unsuccessful ones in deriving this conclusion. The application of exploratory factor analysis, call erection is visible in the analysis.

RESEARCH OBJECTIVES

1. To study concept of financial self-efficacy.
2. To identify the components of financial self-efficacy and evaluate the perception on each of the component by individual respondents in Bengaluru Urban City
3. To offer suggestions based on the available findings of the study.

SCOPE OF THE STUDY

The study undertaken "An Empirical Study on Women Financial Self-Efficacy in Bengaluru Urban District" establishes the relationship between the components of human psychology and demography, under that financial self-efficacy is considered by extracting the variables as financial knowledge, financial behavior and financial attitude. The psychology is studied on the above-mentioned parameters and no other part of psychology is considered for the study. The relationship between establishing the behavior through knowledge and attitude is described under the study as proved by the researchers in the past, the empirical evidences are limited only from the respondents of Bengaluru which comprises of hybrid population with high migration.

METHODOLOGY

The study is Empirical, the data is based on the questionnaire. The study constructs are derived based on the review of literature conducted. The collected data is structured as per the requirement of the paper to derive the desired outcome.

Methods of data collection

Primary data is collected from structure questionnaire from the taxpayers in Bengaluru urbandistrict, secondary data required is collected from journals, newspapers, magazines and any other published sources by giving proper quotations.



**Umamaheswari and Pramod****Sampling**

Cluster Random sampling is followed in distribution of structured questionnaire, respondents are women, the questionnaire data collection is restricted to the jurisdiction of Bengaluru, the data available is converted as per the requirement of the research to draw conclusions based on analysis.

Model of the study**Statistical tools applied**

The statistical tools are applied in stages, initially to the reliability testing of the questionnaire Cronbach alpha analysis is used and based on the objectives of the study regression analysis is used to prove the hypothesis.

ANALYSIS AND INTERPRETATION OF DATA

The above table 1 indicates three different variables results, tested under Crown Bach Alpa. The outcome clearly indicates that the reliability of the questions as the measured value is an excess of 0.7.

Financial knowledge

From the above analysis, it is evident that the women are more familiar about the assets won by them, from the received data the spending is based on the review and purely based on monthly financial planning.

Financial Literacy

From the above statistics it is evident that women tend to understand the terminologies that is made in the statement of the bank account.

Financial Attitude

Considering the compliance factor most of the women have given the opinion that they understand a consequences of non-filing of income tax returns on time. The statistics for the reveals that the deduction permitted as per the act is known to the women force. From the above table, it is evident that the significance of income with the financial literacy and attitude is evident. The acceptance of relationship **alternate hypothesis** is accepted. From the above table, it is evident that the significance of Qualification with all the three variables is evident. The acceptance of relationship **alternate hypothesis** is accepted. From the above table, it is evident that the significance of age with all the three variables is evident. The acceptance of relationship **alternate hypothesis** is accepted. From the above table, it is evident that the significance of income with the financial literacy and attitude is evident. The acceptance of relationship **alternate hypothesis** is accepted. From the above table, it is evident that the significance of age with all the three variables is evident. The acceptance of relationship **alternate hypothesis** is accepted.

CONCLUSIONS AND SUGGESTIONS

There is the significant relationship between financial self-efficacy and financial inclusion, there is lot of variation in the demographic factors in utilization of formal financial services (Mindra, R., & Moya, M,2017). The gap in the financial knowledge is acting as major constraint in effectively managing the financial affairs. The level of financial awareness among the respondents indicates their readiness towards financial planning without dependent on professionals (Boon, T. H, et.al (2011)). The study reveals that irrespective of the level of income in result to savings more rather than spending. The mode of savings preferred was risk free Bank deposits (Bhavsar, H. N. (2013)) It is necessary on the part of the government to provide the sufficient financial knowledge and training to the earning women (Baluja, G. (2016)).At the Inception in the academic scenario, it is advisable to have a separate paper for all disciplines to overcome the problems faced by Technical Education women on finance (Trowler, P. R. (1998)).It opens up to possibilities of researches to come out with new saving plans to ensure that the safety of the principal amount is not disturbed (Whyte, W. F., Greenwood, D. J., & Lazes, P. (1989))





REFERENCES

1. Asandimitra, N., &Kautsar, A. (2019). The influence of financial information, financial self-efficacy, and emotional intelligence to financial management behavior of female lecturer. *Humanities & Social Sciences Reviews*, 7(6), 1112-1124.
2. Asebedo, S. D., & Seay, M. C. (2018). Financial self-efficacy and the saving behavior of JFCP_29_2_A15_357-368-retirees. *Journal of Financial Counseling and Planning*, 29(2), 357-368.
3. Asebedo, S. D., Seay, M. C., Archuleta, K., & Brase, G. (2019). The psychological predictors of older preretirees' financial self-efficacy. *Journal of Behavioral Finance*, 20(2), 127-138.
4. Bernheim, B. D. (2002). Taxation and saving. In *Handbook of public economics* (Vol. 3, pp. 1173-1249). Elsevier.
5. Bhavsar, H. N. (2013). A Study of Saving and Investment Pattern of School Teachers with Special Reference to Ahmednagar City, alMaharashtra. *IBMRD's Journal of Management & Research*, 2(1), 256-267.
6. Boon, T. H., Yee, H. S., & Ting, H. W. (2011). Financial literacy and personal financial planning in Klang Valley, Malaysia. *International Journal of Economics and Management*, 5(1), 149-168.
7. Buettner, T., Erbe, K., & Grimm, V. (2019). Tax planning of married couples and intra-household income inequality. *Journal of Public Economics*, 179, 104048.
8. Buitter, W. H. (1985). A guide to public sector debt and deficits. *Economic policy*, 1(1), 13-61.
9. Cechovsky, N. (2018). The importance of tax knowledge for tax compliance: A study on the tax literacy of vocational business students. In *European Conference on Educational Research (ECER), Vocational Education and Training Network (VETNET)*, September (pp. 113-121).
10. De Carvalho, F. J. C. (2015). *Liquidity preference and monetary economies*. Routledge.
11. Dhongde, S., & Epper, V. Tax Saving Investment Strategies among Salaried Individuals in Aurangabad City.
12. Dietz, B. E., Carrozza, M., & Ritchey, P. N. (2003). Does financial self-efficacy explain gender differences in retirement saving strategies? *Journal of women & aging*, 15(4), 83-96.
13. Farrell, L., Fry, T. R., & Risse, L. (2016). The significance of financial self-efficacy in explaining women's personal finance behavior. *Journal of economic psychology*, 54, 85-99.
14. Gamst-Klaussen, T., Steel, P., & Svardal, F. (2019). Procrastination and personal finances: Exploring the roles of planning and financial self-efficacy. *Frontiers in psychology*, 10, 775.
15. Gautam, S., & Gautam, L. (2013). Income tax planning: A study of tax saving instruments. *International Journal of Management and Social Sciences Research (IJMSSR)*, 2(5), 83.
16. Geetha, C. A. (2016). A study on awareness level of salaried class on tax laws and tax planning measures. *Bharath Matha Journal of Interdisciplinary Studies*, 3(1), 72-90.
17. Trowler, P. R. (1998). *Academics Responding to Change. New Higher Education Frameworks and Academic Cultures*. SRHE, Open University, 325 Chestnut Street, Philadelphia, PA 19106.
18. Asandimitra, N., &Kautsar, A. (2019). The influence of financial information, financial self-efficacy, and emotional intelligence to financial management behavior of female lecturer. *Humanities & Social Sciences Reviews*, 7(6), 1112-1124.
19. Asebedo, S. D., & Seay, M. C. (2018). Financial self-efficacy and the saving behavior of JFCP_29_2_A15_357-368-retirees. *Journal of Financial Counseling and Planning*, 29(2), 357-368.
20. Asebedo, S. D., Seay, M. C., Archuleta, K., & Brase, G. (2019). The psychological predictors of older preretirees' financial self-efficacy. *Journal of Behavioral Finance*, 20(2), 127-138.
21. Bernheim, B. D. (2002). Taxation and saving. In *Handbook of public economics* (Vol. 3, pp. 1173-1249). Elsevier.
22. Bhavsar, H. N. (2013). A Study of Saving and Investment Pattern of School Teachers with Special Reference to Ahmednagar City, alMaharashtra. *IBMRD's Journal of Management & Research*, 2(1), 256-267.
23. Boon, T. H., Yee, H. S., & Ting, H. W. (2011). Financial literacy and personal financial planning in Klang Valley, Malaysia. *International Journal of Economics and Management*, 5(1), 149-168.
24. Buettner, T., Erbe, K., & Grimm, V. (2019). Tax planning of married couples and intra-household income inequality. *Journal of Public Economics*, 179, 104048.
25. Buitter, W. H. (1985). A guide to public sector debt and deficits. *Economic policy*, 1(1), 13-61.





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26. Cechovsky, N. (2018). The importance of tax knowledge for tax compliance: A study on the tax literacy of vocational business students. In European Conference on Educational Research (ECER), Vocational Education and Training Network (VETNET), September (pp. 113-121).
27. De Carvalho, F. J. C. (2015). Liquidity preference and monetary economies. Routledge.
28. Dhongde, S., & Epper, V. Tax Saving Investment Strategies among Salaried Individuals in Aurangabad City.
29. Dietz, B. E., Carrozza, M., & Ritchey, P. N. (2003). Does financial self-efficacy explain gender differences in retirement saving strategies? *Journal of women & aging*, 15(4), 83-96.
30. Farrell, L., Fry, T. R., & Risse, L. (2016). The significance of financial self-efficacy in explaining women's personal finance behavior. *Journal of economic psychology*, 54, 85-99.
31. Gamst-Klaussen, T., Steel, P., & Svartdal, F. (2019). Procrastination and personal finances: Exploring the roles of planning and financial self-efficacy. *Frontiers in psychology*, 10, 775.
32. Gautam, S., & Gautam, L. (2013). Income tax planning: A study of tax saving instruments. *International Journal of Management and Social Sciences Research (IJMSSR)*, 2(5), 83.
33. Geetha, C. A. (2016). A study on awareness level of salaried class on tax laws and tax planning measures. *Bharath Matha Journal of Interdisciplinary Studies*, 3(1), 72-90.
34. Trowler, P. R. (1998). *Academics Responding to Change*. New Higher Education Frameworks and Academic Cultures. SRHE, Open University, 325 Chestnut Street, Philadelphia, PA 19106.

Hypothesis

Ho	There is no direct relationship between demographic variables and financial self-efficacy
H1	There is direct relationship between demographic variables and financial self-efficacy

Table 1: Reliability test

Variable	Cronbach alpha outcome	Number of constructs	Results
Financial knowledge	0.85	10	Reliable
Financial Behaviour	0.92	14	Reliable
Financial Attitude	0.83	7	Reliable

Table 2: Table Showing Individual Results of Mean and Standard Deviation

Constructs	Mean	SD
I spend money purely based on monthly financial planning	3.67	1.19
I observe my financial planning regularly	3.59	1.39
I review my spending	3.74	1.24
I record all my expenses	3.41	1.15
I am aware of the value of the assets owned by me	3.85	1.19
I plan and save every month out of my income	3.52	1.31
I am very cautious in spending money	3.39	1.16
I have emergency savings	3.67	1.17
I am prepared for any kind of financial emergencies	3.5	1.21
I review my overall financial position regularly	3.59	1.33
I am aware of the prevailing interest rate on various saving instruments in the market	3.54	1.11
I am aware of the rate of interest charged by the banks on borrowings from various loan schemes	3.59	1.07
I am aware of the importance of paying EMI on time to maintain good credit rating	3.76	1.23
I am aware of financial terminologies and reading the statement of my bank account	3.91	1.07
I am aware of investing in stock market based on individual decision	3.33	1.23
I am aware of the deductions offered on certain notified investments under section 80 of the income tax act	3.61	1.02
I am aware of those investments through which I can borrow loan in case of emergencies	3.41	1.18





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I am aware of the tax regulations prevailing in the country.	3.67	1.12
I am aware of the dates of filing my income tax return	3.8	1.17
I understand the consequences of non-filing of income tax return within the due date.	3.78	1.19
I am aware of the documentary requirements before filing the tax returns	3.74	1.16
I am aware of the deductions permitted as per the act.	3.76	1.08
I understand the tax implications with regard to new and old tax regime in India.	3.63	1.2
I am aware of the rebates permissible for different income groups	3.57	1.09
I make savings by analysing the investment avenue in depth	3.43	1.09
I make savings based on duration since the investment avenue is existing	3.57	1.11
I make savings considering the retirement benefits	3.43	1.26
I make savings based on assured returns of my investment avenue	3.65	1.12
I make savings considering the safety of the principal amount	3.83	1.06
I make savings based on ability to borrow loan based on investment	3.41	1.22
I make savings to obtain the tax benefits	3.7	1.07

Table 3: Indicating Income Relationship with Variables P- Values

Financial knowledge	0.051097
Financial literacy	0.009029
Financial attitude	0.009029

Table 4: Indicating Qualification Relationship with Variables P- Values

Financial knowledge	0.00000297911
Financial literacy	0.00000297911
Financial attitude	0.000506084

Table 5: Indicating Age Relationship with Variables P- Values

Financial knowledge	0.001443
Financial literacy	0.00000749
Financial attitude	0.000261

Table 6: Indicating Occupation Relationship with Variables P- Values

Financial knowledge	0.051817
Financial literacy	0.028358
Financial attitude	0.017064

Table 7: Indicating Experience in field of finance Relationship with Variables P- Values

Financial knowledge	0.003402
Financial literacy	0.001072
Financial attitude	0.004977



Figure :1

