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The journal has provided an opportunity and space to the Crossian scholars, Professors and research guides of our institution and other institutions at national and international levels. This little, yet, vibrant reverberation of intellectual sharing will definitely generate new knowledge and ignite and unleash power to research within the visionary researchers.

Crossian Resonance strives to keep up the standard from the first issue and all the papers published in this issue were assessed by competent referee editors and were recommended for publication. This journal is committed to the development and regeneration of the nation with the scope of providing an open and common platform to launch a united vision and empowerment of innovative knowledge.

May this endeavour grow and remain evergreen like an olive tree to create renewed awareness, dimensional consciousness and enlightenment.

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Signed Product and Signed Total Product Domination Number of Some Standard Graphs

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ABSTRACT

This paper explores the signed product domination number and signed total product domination number of various standard graphs. The paper provides explicit computations and proofs for these domination numbers across different graph classes including paths, cycles, complete graphs, and bipartite graphs.

Keywords: Signed Product Domination Number, Signed Total Product Domination Number

1. Introduction

Graph theory is a vital branch in combinatorial mathematics, offering critical insights into the structural properties of networks, paths, and cycles. Domination in graphs, particularly through signed and product functions, has emerged as a significant area of study due to its applications in network theory, optimization, and algorithm design. This paper focuses on two specialized domination parameters: the signed product domination number $\gamma_{s^*}(G)$ and the signed total product domination number $\gamma_{(st)^*}(G)$. By a graph we mean a finite, undirected, connected graph without loops or multiple edges. Terms not defined here are used in the sense of [1].

Dunbar introduced the concept of signed dominating function. Let $G = (V, E)$ be a graph. A function $f: V(G) \rightarrow \{-1, 1\}$ is a signed dominating function if $f(N[v]) = \sum_{u \in N[v]} f(u) \geq 1$ for all $v \in V(G)$. For a real valued function f the weight of f is $w(f) = \sum_{v \in V} f(v)$ [2]. The minimum weight $w(f) = f(V(G)) = \sum_{x \in V(G)} f(x)$ taken over all signed dominating functions is the signed domination number of G . It is denoted by $\gamma_s(G)$. A function $f: V(G) \rightarrow \{-1, 1\}$ is a signed total dominating function if $f(N(v)) = \sum_{u \in N(v)} f(u) \geq 1$ for all $v \in V(G)$ [3]. The minimum weight $w(f) = f(V(G)) = \sum_{x \in V(G)} f(x)$ taken over all signed total dominating functions is the signed domination number of G . It is denoted by $\gamma_{st}(G)$. Signed domination number of complete multipartite graph and some standard graphs are found in [4, 5]. In this

paper signed product dominating function and signed total product dominating function are introduced. Also signed product domination number and signed total product domination number of paths, cycle, complete and bipartite graphs are found.

2. Main Results

Definition 2.1. Let $G = (V, E)$ be a graph. A function $f : V(G) \rightarrow \{-1, 1\}$ is a signed product dominating function if f is a signed dominating function and $\prod f(N[v]) = \prod_{u \in N[v]} f(u) = 1$ for all $v \in V(G)$.

Definition 2.2. The minimum weight $w(f) = f(V(G)) = \sum_{x \in V(G)} f(x)$ taken over all signed product dominating functions is the signed product domination number of G . It is denoted by $\gamma_{s^*}(G)$.

Definition 2.3. Let $G = (V, E)$ be a graph. A function $f : V(G) \rightarrow \{-1, 1\}$ is a signed total product dominating function if f is a signed total dominating function and $\prod f(N(v)) = \prod_{u \in N(v)} f(u) = 1$ for all $v \in V(G)$.

Definition 2.4. The minimum weight $w(f) = f(V(G)) = \sum_{x \in V(G)} f(x)$ taken over all signed total product dominating functions is the signed total product domination number of G . It is denoted by $\gamma_{(st)^*}(G)$.

Theorem 2.5. For a path P_n , $\gamma_{s^*}(P_n) = n$.

Proof. Let $f : V(P_n) \rightarrow \{-1, 1\}$ be a signed product dominating function. Then $f(v) = +1 \forall v \in V(P_n)$ otherwise $\prod_{u \in N[v]} f(u) = -1$ for some $v \in V(P_n)$. Hence $\gamma_{s^*}(P_n) = n$.

Theorem 2.6. For a cycle C_n , $\gamma_{s^*}(C_n) = n$.

Proof. Let $f : V(C_n) \rightarrow \{-1, 1\}$ be a signed product dominating function. Then $f(v) = +1 \forall v \in V(C_n)$ otherwise $\prod_{u \in N[v]} f(u) = -1$ for some $v \in V(C_n)$, since every vertex of C_n has degree 2. Hence $\gamma_{s^*}(C_n) = n$.

Theorem 2.7. Let G be a complete graph. Then the signed product domination number of G is

$$\gamma_{s^*}(G) = \begin{cases} 1 & \text{if } n \text{ is odd and } \frac{n-1}{2} \text{ even} \\ 2 & \text{if } n \text{ is even and } \frac{n}{2} - 1 \text{ even} \\ 3 & \text{if } n \text{ is odd and } \frac{n-1}{2} \text{ odd} \\ 4 & \text{if } n \text{ is even and } \frac{n}{2} - 1 \text{ odd} \end{cases}$$

Proof. Let $f : V(G) \rightarrow \{-1, 1\}$ be a signed product dominating function with $w(f) = \gamma_{s^*}(G)$. Then

$$\sum_{v \in N[u]} f(v) \geq 1 \text{ and } \prod_{v \in N[u]} f(v) = 1.$$

Let $A = \{v \in V(G) | f(v) = 1\}$, $B = \{v \in V(G) | f(v) = -1\}$. Since G is a complete graph, $\sum_{v \in N[u]} f(v) = f(V) = w(f)$.

$$|A| - |B| \geq 1$$

$$|A| \geq 1 + |B|$$

$$|A| + |B| = n$$

This implies that $n - |B| \geq 1 + |B|$

$$|B| \leq \frac{n-1}{2}.$$

Case 1: n is odd and $\frac{n-1}{2}$ is even

Since $\frac{n-1}{2}$ is even, $\prod_{v \in N[u]} f(v) = 1$ if $|B| = \frac{n-1}{2}$

$$\text{Hence } w(f) = \frac{n+1}{2} - \frac{n-1}{2} = 1.$$

Case 2: n is odd and $\frac{n-1}{2}$ is odd.

Since $\frac{n-1}{2}$ is odd and $|B| \leq \frac{n-1}{2}$, $\prod_{v \in N[u]} f(v) = -1$ if $|B| = \frac{n-1}{2}$

$$\text{Hence } |B| = \frac{n+1}{2} - 1 = \frac{n-3}{2}.$$

$$\text{This implies } w(f) = \frac{n+3}{2} - \frac{n-3}{2} = 3$$

Case 3: n even and $\frac{n}{2} - 1$ is even.

$$\text{We have } |B| \leq \frac{n-1}{2}.$$

Also, since n is even $\frac{n-1}{2}$ is not an integer.

$$\text{Hence } |B| \leq \left\lfloor \frac{n-1}{2} \right\rfloor = \frac{n}{2} - 1.$$

Now if $|B| = \frac{n}{2} - 1$, then $\prod_{v \in N[u]} f(v) = 1$

$$\text{Thus } w(f) = \frac{n+2}{2} - \frac{n-2}{2} = 2.$$

Case 4: n even and $\frac{n}{2} - 1$ is odd.

Since n is even $\frac{n-1}{2}$ is not an integer.

$$\text{Hence } |B| \leq \left\lfloor \frac{n-1}{2} \right\rfloor = \frac{n}{2} - 1.$$

Now if $|B| = n/2 - 1$, then $\prod_{v \in N[u]} f(v) = -1$

$$\text{Thus } w(f) = \frac{n+2}{2} - \frac{n-2}{2} = 2.$$

which implies that f is not a signed product dominating function.

$$\text{Thus } |B| = \frac{n}{2} - 1 - 1 = \frac{n-4}{2}.$$

Therefore $w(f) = \frac{n+4}{2} - \frac{n-4}{2} = 4$

Theorem 2.8. For a complete bipartite graph $K_{p,q}, p \leq q, \gamma_{s^*}(K_{p,q}) = p + q$.

Proof. Let V_1 and V_2 be the partite sets with $V_1 = \{v_{1,j} \mid 1 \leq j \leq p\}, V_2 = \{v_{2,j} \mid 1 \leq j \leq q\}$.

Let f be a signed product dominating function with minimum weight.

Then $f[N[v_{i,j}]] = f(v_{i,j}) + f[V/V_i] \geq 1, i = 1, 1 \leq j \leq p,$

$i = 2, 1 \leq j \leq q$ and

$$\prod f(N[v_{i,j}]) = \prod_{u_{i,j} \in N[v_{i,j}]} f(u_{i,j}) = f(v_{i,j}) \times \prod f[V/V_i] = 1, \\ i = 1, 2, 1 \leq j \leq p \leq q.$$

Thus, if $f(v_{i,j}) = -1$, then $\prod f[V/V_i] = -1$.

Also, if $f(v_{i,j}) = 1$, then $\prod f[V/V_i] = 1$.

Let $A = \{v \in V(K_{p,q}) \mid f(v) = 1\}, B = \{v \in V(K_{p,q}) \mid f(v) = -1\}$.

Claim: Either $V_i \subseteq B$ or $v_{i,j} \notin B$ for all $v_{i,j} \in V_i$.

Suppose V_i is not contained in B .

Then there is a vertex $v_{i,j} \in V_i$ such that $f(v_{i,j}) = 1$

Thus $\prod f[V/V_i] = 1$

Assume that $v_{i,j} \in B$ for some $v_{i,j} \in V_i$, then $f(v_{i,j}) = -1$.

$$\prod f(N[v_{i,j}]) = f(v_{i,j}) \times \prod f[V/V_i] = -1,$$

This implies f is not a signed product dominating function.

Hence $v_{i,j} \notin B$ for all $v_{i,j} \in V_i$

Claim: $B = \emptyset$

Suppose $B \neq \emptyset$, then there is a vertex $v_{i,j} \in B$. Then by claim 1, $V_i \subseteq B$ for at least one $i, i = 1, 2$. Thus for $v_{k,j} \in V_k, k \neq i, k = 1, 2,$

$f(N[v_{k,j}]) = f(v_{k,j}) + f[V/V_k] < 1$, since $f[V/V_k] = f[V_i] < 0$.

This implies f is not a signed product dominating function, which is a contradiction.

Thus $B = \emptyset$.

Hence $\gamma_{s^*}(K_{p,q}) = w(f) = |A| - |B| = p + q$.

Theorem 2.9. For a complete tripartite graph K_{n_1, n_2, n_3} , the signed product domination number is $\gamma_{s^*}(K_{n_1, n_2, n_3}) = n_1 + n_2 + n_3$.

Proof. Let $G = K_{n_1, n_2, n_3}$

$$V(G) = \{v_{i,j} \mid 1 \leq j \leq n_i\}, i = 1, 2, 3.$$

Also let f be a signed product dominating function with $w(f) = \gamma_{S^*}(G)$.

Then for $1 \leq i \leq 3, 1 \leq j \leq n_i$,

$$f(N_G[v_{i,j}]) = f(v_{i,j}) + f[V/V_i] \geq 1$$

and

$$\prod f(N_G[v_{i,j}]) = f(v_{i,j}) \times \prod f[V/V_i] = 1.$$

Claim 1: Either $V_i \subseteq B$ or $v_{i,j} \notin B$ for all $v_{i,j} \in V_i$.

Suppose V_i is not contained in B .

Then there is a vertex $v_{i,j} \in V_i$ such that $f(v_{i,j}) = 1$

Thus $\prod f[V/V_i] = 1$, since $\prod f(N_G[v_{i,j}]) = 1$.

If there is another element $v_{i,k} \in B$ for some $v_{i,k} \in V_i$, then $f(v_{i,k}) = -1$

This implies $\prod f(N_G[v_{i,j}]) = f(v_{i,j}) \times \prod f[V/V_i] = -1$,

This implies f is not a signed product dominating function.

Thus $v_{i,j} \notin B$ for all $v_{i,j} \in V_i$.

Claim 2:

If $V_i \subseteq B$, there exist a $k, k = 1, 2, 3$ and $i \neq k$ such that $V_k \subseteq B$.

Let $V_i \subseteq B$,

Then by claim 1 $f(v_{i,j}) = -1$ for all $v_{i,j} \in V_i$. Since $\prod f(N_G[v_{i,j}]) = 1$,

$$\prod f[V/V_i] = -1$$

Then there exists at least one vertex $v_{k,j} \in V_k$ such that $f(v_{k,j}) = -1$.

Again, by claim 1 $f(v_{k,j}) = -1$ for all $v_{k,j} \in V_k$.

Hence $V_k \subseteq B$.

Claim 3: $B = \emptyset$

Suppose $B \neq \emptyset$, then there is a vertex $v_{i,j} \in B$. Then by claim 1 and 2, $V_i \subseteq B$ for at least two i 's, $i = 1, 2$.

Consider the partite set k for which V_k not contained in B .

Thus for $v_{k,j} \in V_k, k \neq i, k = 1, 2, 3$

$$f(N_G[v_{k,j}]) = f(v_{k,j}) + f[V/V_k] < 1, \text{ since } f[V/V_k] = f[V_i] < 0.$$

This implies f is not a signed product dominating function, which is a contradiction.

Thus $B = \emptyset$.

Hence $\gamma_{S^*}(K_{n_1, n_2, n_3}) = n_1 + n_2 + n_3$.

Theorem 2.10. For a path $P_n, \gamma_{(st)^*}(P_n) = n$.

Proof. Let $f : V(P_n) \rightarrow \{-1, 1\}$ be a signed total product dominating function. Then $f(v) = +1 \forall v \in V(P_n)$ otherwise $\prod_{u \in N(v)} f(u) = -1$ for some $v \in V(P_n)$.

Hence $\gamma_{(st)^*}(P_n) = n$.

Theorem 2.11. For a cycle C_n , $\gamma_{(st)^*}(C_n) = n$.

Proof. Let $f : V(C_n) \rightarrow \{-1, 1\}$ be a signed total product dominating function. Then $f(v) = +1 \forall v \in V(C_n)$ otherwise $\prod_{u \in N(v)} f(u) = -1$ for some $v \in V(C_n)$, since every vertex of C_n has degree 2.

Hence $\gamma_{(st)^*}(C_n) = n$.

Theorem 2.12. For a complete graph G of order n , $\gamma_{(st)^*}(G) = n$.

Proof. Let $f : V(G) \rightarrow \{-1, 1\}$ be a signed total product dominating function with $w(f) = \gamma_{(st)^*}(G)$. Then

$$\sum_{v \in N(u)} f(v) \geq 1 \text{ and } \prod_{v \in N(u)} f(v) = 1.$$

Let $A = \{v \in V(G) | f(v) = 1\}$, $B = \{v \in V(G) | f(v) = -1\}$.

Claim: $B = \emptyset$

Suppose $B \neq \emptyset$

Then there exist at least one $v \in V(G)$ such that $f(v) = -1$.

Since $\prod_{v \in N(u)} f(v) = 1$, for all $u \in V(G)$ there must be another vertex $u \in V(G)$, such that $f(u) = -1$.

Then $\prod_{v \in N(u)} f(v) = -1$, where $u \in B$, which is a contradiction. Thus

$B = \emptyset$.

This implies $V(G) \subseteq A$.

Hence $\gamma_{(st)^*}(G) = n$.

Theorem 2.13. Let $K_{p,q}$, $p \leq q$ be a complete bipartite graph with p even and $\frac{q}{2} - 1$ even, then

$$\gamma_{(st)^*}(K_{p,q}) = \begin{cases} 3 \text{ if } q \text{ is odd and } \frac{q-1}{2} \text{ even} \\ 4 \text{ if } q \text{ is even and } \frac{q}{2} - 1 \text{ even} \\ 5 \text{ if } q \text{ is odd and } \frac{q-1}{2} \text{ odd} \\ 6 \text{ if } q \text{ is even and } \frac{q}{2} - 1 \text{ odd} \end{cases}.$$

Proof. Let P be a partite set with p vertices and Q be a partite set with q vertices. Let $f : (V(K_{p,q})) \rightarrow \{-1, 1\}$ be a signed total product dominating function with minimum weight.

And $A = \{v \in V(K_{p,q}) | f(v) = 1\}$ and

$$B = \{v \in V(K_{p,q}) | f(v) = -1\}.$$

Also let $P^+ = \{v \in V(P) | f(v) = 1\}$, $P^- = \{v \in V(P) | f(v) = -1\}$

$Q^+ = \{v \in V(Q) | f(v) = 1\}$ and $Q^- = \{v \in V(Q) | f(v) = -1\}$.

Now $|P^-| \leq \frac{p}{2} - 1$, since p is even.

Also, since $\frac{p}{2} - 1$ is even $\prod_{v \in N(u)} f(v) = 1$ for $u \in Q$.

Hence $|P^-| = \frac{p}{2} - 1$ and $|P^+| = \frac{p}{2} + 1$.

Case 1: q is odd and $\frac{q-1}{2}$ even.

Since q is odd $|Q^-| \leq \frac{q-1}{2}$.

Also, since $\frac{q-1}{2}$ is even $\prod_{u \in N(v)} f(u) = 1$ for $v \in P$.

Now

$$\begin{aligned} |B| &= |P^-| + |Q^-| \\ &= \frac{p}{2} - 1 + \frac{q-1}{2} = \frac{p+q-3}{2} \\ |A| &= p + q - \left\lfloor \frac{p+q-3}{2} \right\rfloor = \frac{p+q+3}{2}. \\ \gamma_{(st)^*}(K_{p,q}) &= w(f) = |A| + |B| = 3. \end{aligned}$$

Case 2: q is even and $\frac{q}{2} - 1$ even.

Since q is even $|Q^-| \leq \frac{q}{2} - 1$.

Also, since $\frac{q}{2} - 1$ is even $\prod_{u \in N(v)} f(u) = 1$ for $v \in P$.

Now

$$\begin{aligned} |B| &= |P^-| + |Q^-| \\ &= \frac{p}{2} - 1 + \frac{q}{2} - 1 = \frac{p+q-4}{2} \\ |A| &= p + q - \left\lfloor \frac{p+q-4}{2} \right\rfloor = \frac{p+q+4}{2}. \\ \gamma_{(st)^*}(K_{p,q}) &= w(f) = |A| + |B| = 4. \end{aligned}$$

Case 3: q is odd and $\frac{q-1}{2}$ odd.

Since q is odd $|Q^-| \leq \frac{q-1}{2}$.

Also, since $\frac{q-1}{2}$ is odd $\prod_{u \in N(v)} f(u) = -1$ if $|Q^-| = \frac{q-1}{2}$ for $v \in P$.

Thus $|Q^-| = \frac{q-1}{2} - 1$

Now

$$\begin{aligned} |B| &= |P^-| + |Q^-| \\ &= \frac{p}{2} - 1 + \frac{q-1}{2} - 1 = \frac{p+q-5}{2} \end{aligned}$$

$$|A| = p + q - \left\lfloor \frac{p + q - 5}{2} \right\rfloor = \frac{p + q + 5}{2}.$$

$$\gamma_{(st)^*}(K_{p,q}) = w(f) = |A| + |B| = 5.$$

Case 4: q is even and $\frac{q}{2} - 1$ odd.

Since q is even $|Q^-| \leq \frac{q}{2} - 1$.

Also, since $\frac{q}{2} - 1$ is odd $\prod_{u \in N(v)} f(u) = -1$ if $|Q^-| = \frac{q}{2} - 1$ for $v \in P$.

Thus $|Q^-| = \frac{q}{2} - 2$

Now

$$|B| = |P^-| + |Q^-|$$

$$= \frac{p}{2} - 1 + \frac{q}{2} - 2 = \frac{p + q - 6}{2}$$

$$|A| = p + q - \left\lfloor \frac{p + q - 6}{2} \right\rfloor = \frac{p + q + 6}{2}.$$

$$\gamma_{(st)^*}(K_{p,q}) = w(f) = |A| + |B| = 6.$$

Hence

$$\gamma_{(st)^*}(K_{p,q}) = \begin{cases} 3 & \text{if } q \text{ is odd and } \frac{q-1}{2} \text{ even} \\ 4 & \text{if } q \text{ is even and } \frac{q}{2} - 1 \text{ even} \\ 5 & \text{if } q \text{ is odd and } \frac{q-1}{2} \text{ odd} \\ 6 & \text{if } q \text{ is even and } \frac{q}{2} - 1 \text{ odd} \end{cases}.$$

3. Conclusion

In this paper, we investigated the signed product domination number $\gamma_{s^*}(G)$ and the signed total product domination number $\gamma_{(st)^*}(G)$ for various standard graph classes, including paths, cycles, complete graphs, bipartite graphs, and multipartite graphs. The findings contribute to the broader field of domination in graph theory by extending traditional domination concepts to signed and product-based variations. These results can serve as a foundation for future research into more complex graph structures.

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The Chromatic Restrained Domination Number on Line Graph of Standard Graphs

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ABSTRACT

Let $G = (V, E)$ be a graph and $L(G)$ be the line graph of G . A subset D of $V(G)$ is said to be a chromatic restrained dominating set (or *crd-set*) of G if D is a restrained dominating set of G and $\chi(\langle D \rangle) = \chi(G)$. The minimum cardinality taken over all minimal chromatic restrained dominating sets is called the chromatic restrained domination number of G and is denoted by $\gamma_r^c(G)$. In this paper, we compute the chromatic restrained domination number for the line graph of some standard graphs.

Keywords: Domination, Restrained Domination, Chromatic Number, Line Graphs

AMS Subject Classification: 05C15, 05C69

1. Introduction

All the graphs $G = (V, E) = (n, m)$ considered here are simple, finite and undirected, with neither loops nor multiple edges. For $D \subseteq V$, the subgraph induced by D is denoted by $\langle D \rangle$. The *degree* of a vertex v in a graph G , denoted by $\deg(v)$ is the number of edges incident with v . A k -vertex coloring of a graph, or simply a k -coloring, is an assignment of k -colors to its vertices. The coloring is proper if no two adjacent vertices are assigned the same color. A coloring in which k -colors are used is a k -coloring. A graph is k -colorable if it has a proper k -coloring. The minimum k for which a graph G is k -colorable is called its *chromatic number* and denoted by $\chi(G)$. Graph Theory terminologies which are not defined here can be seen in [1] and [2].

A set $D \subseteq V$ of vertices in a graph G is called a dominating set if every vertex $u \in V$ is either an element of D or is adjacent to an element of D . The minimum cardinality taken over all minimal dominating sets is called the *domination number* of G and is denoted by $\gamma(G)$. A set $D \subseteq V$ is a restrained dominating set if every vertex in $V - D$ is adjacent to a vertex in D and another vertex in $V - D$ [3]. The minimal cardinality taken over all minimal restrained dominating sets is called the *restrained domination number* of G and is denoted by $\gamma_r(G)$. A set D is a γ_r -set if D is a restrained dominating set of cardinalities $\gamma_r(G)$.

For a graph G with edges, the *line graph* $L(G)$ is the graph whose vertices correspond to the edges (lines) of G , and two vertices in $L(G)$ are adjacent if and only if the corresponding edges in G are adjacent (that is, are incident with a common vertex). In 2018, E. Murugan and J. Paulraj Joseph determined the bounds on the sum of the domination number of a graph and its line graph. They also characterised upper and lower bounds on the domination number of line graphs [4]. The *bistar graph* $B_{r,s}$ is the graph obtained by joining the center vertices of two-star graphs $K_{1,r}$ and $K_{1,s}$, $r, s \geq 2$.

A set $D \subseteq V$ is a *chromatic preserving set* or a *cp-set* if $\chi(\langle D \rangle) = \chi(G)$ and the minimum cardinality taken over all cp-set in G is called the *chromatic preserving number* or *cp-number* of G , denoted by $\text{cpn}(G)$. This new concept was introduced by T. N. Janakiraman and M. Poobalaranjani [5]. They also defined the concept of a *dom-chromatic set* of a graph. A subset D of V is said to be a *dom-chromatic set* (or *dc-set*) if D is a dominating set and $\chi(\langle D \rangle) = \chi(G)$. The minimum cardinality taken over all minimal dom-chromatic sets in G is called the *dom-chromatic number* and is denoted by $\gamma_{ch}(G)$. In [6], they determined dom-chromatic numbers for several classes of graphs and established key results in this area. Based on this, S. Balamurugan et al [7], [8], [9], [10] introduced and studied the concepts of chromatic strong domination, chromatic total domination, chromatic connected domination, chromatic weak domination and so on. Additionally, J. Joseline Manora et al [11], [12] explored connected majority dom-chromatic number of a graph and majority dom-chromatic set of a graph. Similar to these works, several authors have explored various types of dom-chromatic sets. In this paper, we study a new domination parameter, the chromatic restrained domination number of line graphs.

2. Chromatic Restrained Domination Number for Line Graphs

In this section, we obtained the chromatic restrained domination number for the line graph of some standard graphs.

Definition 2.1 Let $G = (V, E)$ be a graph and $L(G)$ be the line graph of G . A subset D of V is said to be a *chromatic restrained dominating set* (or *crd-set*) if D is a restrained dominating set and $\chi(\langle D \rangle) = \chi(G)$. The minimum cardinality taken over all minimal chromatic restrained dominating sets is called *chromatic restrained domination number* and is denoted by $\gamma_r^c(G)$. Throughout this paper, we denote the chromatic restrained domination number of line graphs by $\gamma_r^c(L(G))$.

Theorem 2.2 Let $G = K_n$ be the complete graph on n vertices. Then

$$\gamma_r^c(L(K_n)) = \begin{cases} \frac{n(n-1)}{2} - 2 & \text{if } n \text{ is odd, } n \geq 5 \\ n-1 & \text{if } n \text{ is even, } n \geq 4 \end{cases}$$

Proof: Let $V(K_n) = \{v_1, v_2, v_3, \dots, v_n\}$ and $E(K_n) = \{m_{ij}/1 \leq i \leq n, 1 \leq j \leq n, m_{ij} = m_{ji}, i \neq j\}$. Then $V(L(K_n)) = E(K_n)$ with cardinality $\frac{n(n-1)}{2}$. Also $\chi(K_n) = n$.

Case (i): n is odd

Then $\chi(L(K_n)) = n$. Consider $D = \{m_{i(i+1)}/1 \leq i \leq n - 2, i \text{ is odd}\}$ and D is independent. Then D is a restrained dominating set of $L(K_n)$ with cardinality $\lfloor \frac{n}{2} \rfloor$. Since any minimal restrained dominating set is independent, $\chi(\langle D \rangle) = 1 \neq \chi(L(K_n))$. Therefore, D is not a chromatic restrained dominating set. Let $S = V(L(K_n)) - \{m_{12}, m_{13}\}$. Then S is a restrained dominating set and $\chi(\langle S \rangle) = n = \chi(L(K_n))$. Therefore, S is a chromatic restrained dominating set with cardinality $\frac{n(n-1)}{2} - 2$ and $\gamma_r^c(L(K_n)) \leq \frac{n(n-1)}{2} - 2$. We show that S is a minimal chromatic restrained dominating set of $L(K_n)$. Suppose not, then there exists a chromatic restrained dominating set S' such that $S' \subset S$. Then there exists a vertex $x \in S$ and $x \notin S'$. Thus $\chi(\langle S' \rangle) < \chi(L(K_n))$, which is a contradiction. Therefore, S is a minimal chromatic restrained dominating set of $L(K_n)$, so that $\gamma_r^c(L(K_n)) \geq \frac{n(n-1)}{2} - 2$. Hence, $\gamma_r^c(L(K_n)) = \frac{n(n-1)}{2} - 2$, where n is odd.

Case (ii): n is even

Then $\chi(L(K_n)) = n - 1$. Let $D = \{m_{i(i+1)}/1 \leq i \leq n, i \text{ is even}\}$. Then D is a restrained dominating set of $L(K_n)$ with cardinality $\frac{n}{2}$. Since D is independent, $\chi(\langle D \rangle) = 1 \neq \chi(L(K_n))$. Therefore, D is not a chromatic restrained dominating set of $L(K_n)$. Consider $D_i = \{m_{ij}/1 \leq j \leq n, i \neq j\}$. Then D_i^s are the subsets of $V(L(K_n))$ with same cardinality and $\chi(\langle D_i \rangle) = n - 1$. Also D_i^s are restrained dominating sets of $L(K_n)$. Since $\langle D_i \rangle$ is complete, then for any $D_i - \{m_{ij}\}, 1 \leq i \leq n$, the chromatic number is less than $n - 1$. Therefore, D_1, D_2, \dots, D_n are the only sets of $L(K_n)$ with chromatic number $n - 1$ and minimum cardinality. Therefore D_i^s are the chromatic restrained dominating sets of $L(K_n)$ and $\gamma_r^c(L(K_n)) = n - 1$.

Observation 2.3: $\gamma_r^c(L(K_n)) = \begin{cases} 1 & \text{if } n = 2 \\ 3 & \text{if } n = 3 \end{cases}$

Observation 2.4:

(1) For any path P_n ,

$$\gamma_r^c(L(P_n)) = \gamma_r^c(P_{n-1}) = \begin{cases} \frac{n-1}{3} + 2 & \text{if } n \equiv 1 \pmod{3} \\ \lfloor \frac{n-1}{3} \rfloor + 2 & \text{if } n \equiv 2 \pmod{3} \\ \lfloor \frac{n-1}{3} \rfloor + 1 & \text{if } n \equiv 0 \pmod{3} \end{cases}$$

(2) For any cycle C_n ,

- (i) if n is odd, then $\gamma_r^c(L(C_n)) = \gamma_r^c(C_n) = n$
- (ii) if n is even, then

$$\gamma_r^c(L(C_n)) = \gamma_r^c(C_n) = \begin{cases} \lfloor \frac{n}{3} \rfloor & \text{if } n \equiv 1(\text{mod } 3) \\ \lfloor \frac{n}{3} \rfloor + 1 & \text{if } n \equiv 2(\text{mod } 3) \\ \frac{n}{3} + 2 & \text{if } n \equiv 0(\text{mod } 3) \end{cases}$$

Theorem 2.5: For $n \geq 3$, $\gamma_r^c(L(K_{1,n-1})) = n - 1$.

Proof: Let $V(K_{1,n-1}) = \{v_0, v_1, v_2, \dots, v_{n-1}\}$ where $\deg(v_0) = n - 1$ and v_1, v_2, \dots, v_{n-1} are the vertices of degree one. Then $E(K_{1,n-1}) = \{m_i/1 \leq i \leq n - 1, m_i = v_0v_i \in E(K_{1,n-1})\} = V(L(K_{1,n-1}))$. Also $\chi(L(K_{1,n-1})) = n - 1$. Any singleton set D is a restrained dominating set of $L(K_{1,n-1}), n > 3$. Clearly, $\chi(\langle D \rangle) = 1 \neq \chi(L(K_{1,n-1}))$. Therefore, D is not a chromatic restrained dominating set of $L(K_{1,n-1})$. Since $\chi(L(K_{1,n-1})) = n - 1, S = \{m_1, m_2, \dots, m_{n-1}\}$ is the minimal set with respect to the property that the induced subgraph has chromatic number $n - 1$, as $\langle S \rangle$ is a complete graph on $n - 1$ vertices. Also S is a restrained dominating set of $L(K_{1,n-1})$. Therefore, S is a chromatic restrained dominating set of $L(K_{1,n-1})$ with cardinality $|S| = |V(L(K_{1,n-1}))| = n - 1$. Therefore, $\gamma_r^c(L(K_{1,n-1})) = n - 1$.

Theorem 2.6: For $n \geq 4, \gamma_r^c(L(W_n)) = n - 1$.

Proof: Let $V(W_n) = \{v_0, v_1, v_2, \dots, v_{n-1}\}$ with $n - 1$ outer vertices and $E(W_n) = \{m_i, m_{j(j+1)}, m_{1(n-1)}/m_i = v_0v_i, 1 \leq i \leq n - 1, 1 \leq j \leq n - 2\} = V(L(W_n))$. Also, $\deg(v_0) = n - 1$ and $\chi(L(W_n)) = n - 1$. Since v_0 is a vertex of maximum degree in W_n , the induced subgraph of $L(W_n)$ formed from the edges incident with v_0 has chromatic number $n - 1$. Also $D = \{m_i/1 \leq i \leq n - 1\}$ is a restrained dominating set of $L(W_n)$ with cardinality $|D| = n - 1$. Therefore, D is the only chromatic restrained dominating set of $L(W_n)$ with minimum cardinality. Hence, $\gamma_r^c(L(W_n)) = n - 1$.

Theorem 2.7: For any complete bipartite graph $K_{r,s}, \gamma_r^c(L(K_{r,s})) = \max\{r, s\}$.

Proof: Let $V(K_{r,s}) = V_1 \cup V_2$ where $V_1 = \{v_1, v_2, \dots, v_r\}$ and $V_2 = \{u_1, u_2, \dots, u_s\}$. Also $E(K_{r,s}) = \{m_{ij}/m_{ij} = v_iu_j, 1 \leq i \leq r, 1 \leq j \leq s, m_{ij} \neq m_{ji}\} = V(L(K_{r,s}))$ and

$\chi(L(K_{r,s})) = \max\{r, s\}$. Let $r \leq s$. Any set D containing all the edges incident with any vertex in V_2 of $K_{r,s}$ is a restrained dominating set of $L(K_{r,s})$ with $|D| = r$ and $\gamma_r(L(K_{r,s})) \leq r$. Since $\gamma(L(K_{r,s})) = r, \gamma_r(L(K_{r,s})) \geq r$. Therefore, $\gamma_r(L(K_{r,s})) = r$. Since $\langle D \rangle$ is a complete graph on r vertices, $\chi(\langle D \rangle) = r$. If $r = s$, then $\chi(\langle D \rangle) = r = \chi(L(K_{r,s}))$. Therefore, D is a chromatic restrained dominating set of $L(K_{r,s})$. Let $r \neq s$. Then $\chi(\langle D \rangle) \neq \chi(L(K_{r,s}))$ and D is not a chromatic restrained dominating set of $L(K_{r,s})$. Consider $S = \{m_{11}, m_{12}, m_{13}, \dots, m_{1s}\}$ where $m_{11}, m_{12}, m_{13}, \dots, m_{1s}$ are the edges incident with $v_1 \in V_1$. Then S is a restrained dominating set of $L(K_{r,s})$ and $\chi(\langle S \rangle) = s = \max\{r, s\} = \chi(L(K_{r,s}))$, since $\langle S \rangle$ is a complete graph on s vertices. Therefore, S is a chromatic restrained dominating set of $L(K_{r,s})$ and $\gamma_r^c(L(K_{r,s})) \leq |S| = s$. Since $\chi(L(K_{r,s})) = s, \gamma_r^c(L(K_{r,s})) \geq s$. Therefore, $\gamma_r^c(L(K_{r,s})) = s = \max\{r, s\}$.

Theorem 2.8: For any bistar graph $B_{r,s}, \gamma_r^c(L(B_{r,s})) = \max\{r, s\} + 1$.

Proof: Let $V(B_{r,s}) = \{v_0, u_0, v_1, v_2, \dots, v_r, u_{r+1}, u_{r+2}, \dots, u_{r+s}\} = \{v_0, u_0, v_i, u_j / 1 \leq i \leq r, r + 1 \leq j \leq r + s\}$ where v_0 and u_0 are the center vertices of $K_{1,r}$ and $K_{1,s}$ and $|V(B_{r,s})| = r + s + 2$. Then $E(B_{r,s}) = \{m_0, m_i, m_j / m_0 = v_0 u_0, m_i = v_0 v_i, m_j = u_0 u_j, 1 \leq i \leq r, r + 1 \leq j \leq r + s\} = V(L(B_{r,s}))$. Let u_0 be a vertex of maximum degree in $B_{r,s}$ and $\Delta(B_{r,s}) = s + 1$. Also $\chi(L(B_{r,s})) = s + 1$. Consider $D = \{m_0\}$. Then D is a restrained dominating set of $L(B_{r,s})$ and $\gamma_r(L(B_{r,s})) = 1$. Also $\chi(\langle D \rangle) = 1 \neq \chi(L(B_{r,s}))$. Therefore, D is not a chromatic restrained dominating set of $L(B_{r,s})$. Let $S = \{m_0, m_{r+1}, m_{r+2}, \dots, m_{r+s}\}$. Clearly, S is a restrained dominating set of $L(B_{r,s})$. Since $\langle S \rangle$ is a complete graph on $s + 1$ vertices, $\chi(\langle S \rangle) = s + 1 = \chi(L(B_{r,s}))$. Therefore, S is a chromatic restrained dominating set of $L(B_{r,s})$ and $\gamma_r^c(L(B_{r,s})) \leq s + 1$. Since $\{m_0, m_{r+1}, m_{r+2}, \dots, m_{r+s}\}$ is the minimal set with respect to the property that the induced subgraph has chromatic number $s + 1, \gamma_r^c(L(B_{r,s})) \geq s + 1$. Therefore, $\gamma_r^c(L(B_{r,s})) = s + 1 = \max\{r, s\} + 1$.

Theorem 2.9: For any friendship graph $F_m, m \geq 2, \gamma_r^c(L(F_m)) = 3m$.

Proof: Let $|V(F_m)| = 2m + 1$ and $V(F_m) = \{v_0, v_1, v_2, v_3, v_4, \dots, v_{2m-1}, v_{2m}\}$ where v_0 is the vertex of maximum degree in F_m . Then $E(F_m) = \{m_i, m_{j(j+1)} / 1 \leq i \leq 2m, 1 \leq j \leq 2m - 1, j \text{ is odd}\} = V(L(F_m))$. Also, $\chi(L(F_m)) = 2m$. Let $D =$

$\{m_{12}, m_{34}, m_{56}, m_{78}, \dots, m_{(2m-1)(2m)}\}$. Then D is a restrained dominating set of $L(F_m)$ and cardinality of D is m . Therefore, $\gamma_r(L(F_m)) \leq m$. Since $\gamma(L(F_m)) = m, \gamma_r(L(F_m)) \geq m$. Therefore, $\gamma_r(L(F_m)) = m$. Since D is independent, $\chi(\langle D \rangle) = 1 \neq 2m$. Therefore, D is not a chromatic restrained dominating set of $L(F_m)$. Consider $D_1 = \{m_i/1 \leq i \leq 2m\}$. Then D_1 is the minimal set whose induced subgraph has chromatic number $2m$. But D_1 is not a restrained dominating set of $L(F_m)$, since $V(L(F_m)) \setminus D_1$ is an independent set. Therefore, D_1 is not a chromatic restrained dominating set of $L(F_m)$. Thus, for any proper subset $S = V(L(F_m)) - \{m_i\}$ and $V(L(F_m)) - \{m_{j(j+1)}\}$, either $\chi(\langle S \rangle) < 2m$ or S is not a restrained dominating set. Therefore, $V(L(F_m))$ is the only chromatic restrained dominating set of $L(F_m)$ and $\gamma_r^c(L(F_m)) = |V(L(F_m))| = 3m$.

Observation 2.10: For any line graph $L(G)$ of G , $1 \leq \gamma_r^c(L(G)) \leq \frac{n(n-1)}{2} - 2$.

Theorem 2.11: If G is a graph, then $\gamma_r^c(L(G)) = 1$ if and only if $G = K_2$.

Proof: Assume that $\gamma_r^c(L(G)) = 1$. Then $\chi(L(G)) = 1$ and $L(G) = nK_1$ is the only possible line graph with $\chi(L(G)) = 1$. But $\gamma_r^c(nK_1) = n$, for $n \geq 1$. Therefore, $L(G) = K_1$. Then, G is a graph with an edge, which is K_2 . Therefore, $G = K_2$. The converse is trivial.

3. Conclusion

In this paper, we have determined the chromatic restrained domination number for the line graph of certain standard graphs and observed that $1 \leq \gamma_r^c(L(G)) \leq \frac{n(n-1)}{2} - 2$. An encouraging direction for future research is to analyse the extremal graphs that represent the upper limits of the chromatic restrained domination number in line graphs.

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Relatively Prime Domination in Power of Coconut Tree Graph

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ABSTRACT

A subset S of V is said to be dominating set in G if every vertex in $V - S$ is adjacent to at least one vertex in S . A set $S \subseteq V$ is said to be relatively prime dominating set if it is a dominating set with at least two elements and for every pair of vertices u and v in S such that $(d(u), d(v)) = 1$ where d is the degree of the vertex. The minimum cardinality of a relatively prime dominating set is called relatively prime domination number and it is denoted by $\gamma_{rpd}(G)$. If there is no such pair exist, then $\gamma_{rpd}(G) = 0$. This article focuses on exploring the relatively prime domination number within the context of the power of the coconut tree graph, denoted as $CT(m, n)$. The discussion reveals that for the coconut tree graph $CT(m, n)$, the relatively prime domination number, denoted as $\gamma_{rpd}(CT(m, n))$, assumes values of 0, 2, or 3. Additionally, the article describes the computation of the relatively prime domination number for the power of coconut tree graph using the Python programming language.

Keywords: Dominating Set, Domination Number, Relatively Prime Dominating Set, Relatively Prime Domination Number

1 Introduction

By a graph $G = (V, E)$ we mean a finite undirected graph without loops and multiple edges. The order and size of G are denoted by p and q respectively. For graph theoretical terms, we refer to Harary [1] and for terms related to domination we refer to Haynes [2]. A subset S of V is said to be a dominating set in G if every vertex in $V - S$ is adjacent to at least one vertex in S . The domination number $\gamma(G)$ is the minimum cardinality of a dominating set in G . Berge [3] and Ore [4] formulated the concept of domination in graphs. It was further extended to define many other dominations related parameters in graphs. In 2017, C. Jayasekaran and A. Jancy Vini [5] have introduced the concept of relatively prime domination number in graph theory. Let G be a non-trivial graph. A set $S \subseteq V$ is said to be a relatively prime dominating set if it is a dominating set and for every pair of vertices u and v in S such that $(d(u), d(v)) = 1$. The minimum cardinality of a relatively prime dominating set is called the relatively prime domination number and it is denoted by $\gamma_{rpd}(G)$. A Coconut

Tree CT (m, n) is the graph obtained from the path P_n by appending m new pendent edges at an end vertex of P_n . The k^{th} power G^k of an undirected graph G is a graph that has the same set of vertices, but in which two vertices are adjacent when their distance in G is at most k . In this paper we determine the relatively prime domination number for power of coconut tree graph when $m = 2, 3$. In order to find the relatively prime domination number, we must know the degree of each vertex in the graph. The following results exhibit the degree of vertices in the coconut tree graph and power of coconut tree graph.

2 Distribution of Degree of Vertices

2.1 Coconut Tree Graph

We shall now discuss the distribution of degree of vertices in the Coconut Tree graph. Here, we give name to the end vertex of pendent edges as v_1, v_2, \dots, v_m and the vertices of the path as u_1, u_2, \dots, u_n . All the end vertices $v_1, v_2, \dots, v_m, u_n$ have degree one, the vertex u_1 which is adjacent to all m vertices and u_2 , so that u_1 have degree $(m + 1)$ and all other vertices u_2, u_3, \dots, u_{n-1} have degree two.

For example, consider the coconut tree graph given below

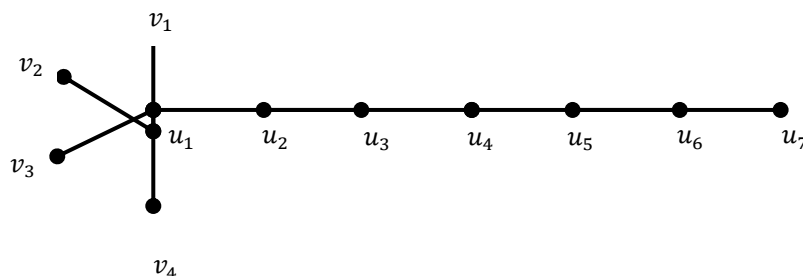


Figure 1

Here, v_1, v_2, v_3, v_4, u_7 have degree one, u_1 have degree five, and all other vertices u_2, u_3, \dots, u_6 have degree two.

2.2 Power of Coconut Tree Graph

The power of the Coconut Tree graph follows a different distribution of degrees. Now, let us assume the power of the Coconut Tree be p . The vertices v_1, v_2, \dots, v_m have degree $m + p - 1$ since each vertex v_m is adjacent to all other v_{m-1} vertices and also adjacent to p vertices of P_n . When $n \geq 2p$, the vertex u_1 is adjacent to each v_m vertices and to p vertices of P_n so that the degree of u_1 is $m + p$. Similar to u_1 the vertex u_2 is adjacent to $m + p$ vertices and also to u_1 . Therefore, the degree of u_2 is $m + p + 1$. Proceeding like this till u_p we have $deg(u_i) = m + p + (i - 1)$ where $1 \leq i \leq p$.

When $n = p + 1$, the vertices u_1, u_2, \dots, u_p have the same degree $m + p$. Each vertex u_i where $i=1,2,\dots,p$ is adjacent to every other vertices of the path since the distance between

them is at most p . The remaining vertex u_n have degree p since it is adjacent to p vertices to the left.

When $n = p + i$ where $2 \leq i \leq p - 1$, the vertices u_i, u_{i+1}, \dots, u_p have same degree $m + p + (i - 1)$ for the graph with $n = p + i$ since the number of vertices to the right of each vertex is decreasing by 1 when i increasing. The vertex u_1 is adjacent to each v_m vertices and to p vertices of P_n so that the degree of u_1 is $m + p$. Similar to u_1 , the vertex u_2 is adjacent to $m + p$ vertices and also to u_1 . Therefore, the degree of u_2 is $m + p + 1$. Proceeding like this till u_{i-1} we have $deg(u_j) = m + p + (j - 1)$ where $1 \leq j \leq (i - 1)$.

These conditions follow until u_p because the vertices v_1, v_2, \dots, v_m are adjacent to u_p^{th} vertex of P_n . And the remaining vertices of the graph with $n \geq 2p$, $u_{p+1}, u_{p+2}, \dots, u_{n-p}$ have degree $2p$ since each vertex covers p vertices on each side of it in the path P_n . For the graph with $n = p + 1$ and $n = p + i$, where $2 \leq i \leq p - 1$ have no vertices of degree $2p$, since $n < 2p$ and the remaining vertices u_k where $n - p + 1 \leq k \leq n$ has $deg(u_k) = 2p - l$ where $1 \leq l \leq p$.

Theorem 2.1. For any CT (m, n) graph $\gamma_{rpd}(CT(m, n)^p) = 0$ if $2 \leq n \leq p$ where $p \geq 2$.

Proof: Let G be a $CT(m, n)^p$ graph. As the power of G is a complete graph, the degree of each vertex is the same.

i.e.) Degree of each vertex is $m+n-1$. Hence a relatively prime dominating set does not exist.

$\therefore \gamma_{rpd}((CT(m, n))^p) = 0$ if $2 \leq n \leq p$.

3 Relatively Prime Domination Number on Power of Coconut Tree Graph when $m = 2$

This section covers the relatively prime domination number on power of coconut tree graphs when the number of pendant edges is 2. The relatively prime domination number for such graphs will be 2 or 3 or 0.

Theorem 3.1. For any Coconut Tree $CT(2, n)$ graph,

$$\gamma_{rpd}((CT(2, n))^p) = 2 \text{ if } p + 1 \leq n \leq 4p + 1 \text{ where } p \geq 2.$$

Proof: Let G be a Coconut Tree $(CT(2, n))^p$ graph. We shall prove this by two cases.

Case 1: $p + 1 \leq n \leq 2p$ where $p \geq 2$

As the graph G has $p + i + 2$ vertices and u_p has degree $p + i + 1$ where $1 \leq i \leq p$, the vertex u_p covers all the vertices of G . Since the relatively prime dominating set contains at least two vertices. We proceed by two cases,

Subcase 1.1: $n = p + 1$

We choose two vertices u_p and v_i where $i = 1$ or 2 .

$\therefore \{u_p, v_i\}$ is a dominating set of G .

Since $(d(u_p), d(v_i)) = (p + 2, p + 1) = 1$, the relatively prime dominating set is $\{u_p, v_i\}$

and hence $\gamma_{rpd}((CT(2, n))^p) = 2$.

Subcase 1.2: $p + 2 \leq n \leq 2p$

We choose two vertices u_p and u_{p-i} where $i=p-1, p-2, \dots, 2, 1$ for the graph with $n = p + 2, p + 3, \dots, 2p$ respectively.

$\therefore \{u_p, u_{p-i}\}$ is a dominating set of G .

Since $(d(u_p), d(u_{p-i})) = (p + 1 + j, p + j) = 1$ where $2 \leq j \leq p$, the relatively prime dominating set is $\{u_p, u_{p-i}\}$ and hence $\gamma_{rpd}((CT(2, n))^p) = 2$

Case 2: $2p + 1 \leq n \leq 4p + 1$

As the graph $(CT(2, n))^p$ has $n + 2$ vertices and the vertex u_p has degree $2p + 1$, the vertex u_p covers $v_1, v_2, u_1, u_2, \dots, u_{p-1}, u_{p+1}, \dots, u_{2p}$. Since $n = 2p + i$ where $1 \leq i \leq 2p + 1$, the graph has i vertices remaining and the vertex u_{n-p} has degree $2p$. The vertex u_{n-p} covers all the remaining i vertices.

$\therefore \{u_p, u_{n-p}\}$ is a dominating set of G .

Since $(d(u_p), d(u_{n-p})) = ((2p + 1), (2p)) = 1$, the relatively prime dominating set is $\{u_p, u_{n-p}\}$ and hence $\gamma_{rpd}((CT(2, n))^p) = 2$.

Theorem 3.2. For any $CT(2, n)$ graph, $\gamma_{rpd}((CT(2, n))^p) = 3$ if $4p + 2 \leq n \leq 6p + 1$ where $p \geq 2$.

Proof: As the graph $(CT(2, n))^p$ has $n + 2$ vertices and the vertex u_p has degree $2p + 1$, the vertex u_p covers $v_1, v_2, u_1, u_2, \dots, u_{p-1}, u_{p+1}, \dots, u_{2p}$. Since $n = 2p + i$ where $2p + 2 \leq i \leq 4p + 1$, the graph has i vertices remaining and the vertex u_{3p+1} has degree $2p$. The vertex u_{3p+1} covers $u_{2p+1}, \dots, u_{3p}, u_{3p+2}, \dots, u_{4p+1}$. Since $n = 4p + 1 + j$, where $1 \leq j \leq 2p$, the graph has remaining j vertices and the vertex u_{n-p+1} has degree $2p - 1$. The vertex u_{n-p+1} covers the remaining vertices j .

$\therefore \{u_p, u_{3p+1}, u_{n-p+1}\}$ is a dominating set.

Since $(d(u_p), d(u_{n-p+1})) = ((2p + 1), (2p - 1)) = 1$,

$(d(u_p), d(u_{3p+1})) = ((2p + 1), (2p)) = 1$, $(d(u_{3p+1}), d(u_{n-p+1})) = ((2p), (2p - 1)) = 1$, $(d(u_p), d(u_{3p+1}), d(u_{n-p+1})) = 1$, the relatively prime dominating set is $\{u_p, u_{3p+1}, u_{n-p+1}\}$.

$\therefore \gamma_{rpd}((CT(2, n))^p) = 3$.

Theorem 3.3. For any $CT(2, n)$ graph, $\gamma_{rpd}((CT(2, n))^p) = 0$ if $n \geq 6p + 2$ where $p \geq 2$.

Proof: Let G be a $(CT(2, n))^p$ graph. By theorem 3.2, $6p + 1$ vertices are covered using u_p, u_{3p+1}, u_{n-p+1} vertices. But to cover the remaining vertices, we have to choose a vertex u_i of degree $2p$ where $3p + 2 \leq i \leq n - p$. Then, $(d(u_{3p+1}), d(u_i)) = ((2p), (2p)) \neq 1$. Relatively prime dominating set does not exist.

$$\therefore \gamma_{rpd}((CT(2, n))^p) = 0 \text{ if } n \geq 6p + 2.$$

4 Relatively Prime Domination Number on Power of Coconut Tree Graph when $m = 3$

This section covers the relatively prime domination number on power of coconut tree graphs when the number of pendant edges is 3. The relatively prime domination number for such graphs will be 2 or 3 or 0.

Theorem 4.1. For any Coconut Tree $CT(3, n)$ graph, $\gamma_{rpd}((CT(3, n))^p) = 2$ if $p + 1 \leq n \leq 4p$ where $p \geq 2$.

Proof: Let G be the $(CT(3, n))^p$ graph. We shall prove this by two cases.

Case 1: $p + 1 \leq n \leq 2p$ where $p \geq 2$

As the graph G has $p + i + 3$ vertices and u_p has degree $p + i + 2$ where $1 \leq i \leq p$, the vertex u_p covers all the vertices of G . Since the relatively prime dominating set contains at least two vertices. We proceed by two cases,

Subcase 1.1: $n = p + 1$

We choose two vertices u_p and v_i where $i = 1, 2, 3$.

$\therefore \{u_p, v_i\}$ is a dominating set of G .

Since $(d(u_p), d(v_i)) = (p + 3, p + 2) = 1$, the relatively prime dominating set is $\{u_p, v_i\}$

and hence $\gamma_{rpd}((CT(3, n))^p) = 2$.

Subcase 1.2: $p + 2 \leq n \leq 2p$

We choose two vertices u_p and u_{p-i} where $i = p-1, p-2, \dots, 2, 1$ for the graph with $n = p + 2, p + 3, \dots, 2p$ respectively.

$\therefore \{u_p, u_{p-i}\}$ is a dominating set of G .

Since $(d(u_p), d(u_{p-i})) = (p + j + 2, p + j + 1) = 1$ where $2 \leq j \leq p$, the relatively prime dominating set is $\{u_p, u_{p-i}\}$ and hence $\gamma_{rpd}((CT(3, n))^p) = 2$

Case 2: $2p + 1 \leq n \leq 4p$ where $p \geq 2$

As the graph G has $2p + i + 3$ vertices where $1 \leq i \leq 2p$ and the vertex u_{p-1} has degree $2p + 1$, the vertex u_{p-1} covers $v_1, v_2, v_3, u_1, u_2, \dots, u_{p-2}, u_p, \dots, u_{2p-1}$. Since $n =$

$2p + j - 1$ where $2 \leq j \leq 2p + 1$, the graph has j vertices remaining and the vertex u_{n-p} has degree $2p$. The vertex u_{n-p} covers all the remaining j vertices.

$\therefore \{u_{p-1}, u_{n-p}\}$ is the dominating set of G .

Since $(d(u_{p-1}), d(u_{n-p})) = ((2p + 1), (2p)) = 1$, the relatively prime dominating set is $\{u_{p-1}, u_{n-p}\}$.

$\therefore \gamma_{rpd}((CT(3, n))^p) = 2$ if $2p + 1 \leq n \leq 4p$ where $p \geq 2$

Theorem 4.2. For any $CT(3, n)$ graph, $\gamma_{rpd}((CT(3, n))^p) = 3$ if $4p + 1 \leq n \leq 6p$ where $p \geq 2$.

Proof: Let G be a $(CT(3, n))^p$ graph. As the graph G has $4p + i + 3$ vertices where $1 \leq i \leq 2p$ and the vertex u_{p-1} has degree $2p + 1$, the vertex u_{p-1} covers $v_1, v_2, v_3, u_1, u_2, \dots, u_{p-2}, u_p, \dots, u_{2p-1}$. Since $n = 2p + j - 1$ where $2 \leq j \leq 2p + 1$, the graph has j vertices remaining and the vertex u_{3p} has degree $2p$. The vertex u_{3p} covers $u_{2p}, u_{2p+1}, \dots, u_{3p-1}, u_{3p+1}, \dots, u_{4p}$. Since $n = 4p + k$ where $1 \leq k \leq 2p$, the graph has k vertices remaining and the vertex u_{n-p+1} has degree $2p - 1$.

$\therefore u_{n-p+1}$ cover all the remaining k vertices.

Hence, $\{u_{p-1}, u_{3p}, u_{n-p+1}\}$ is a dominating set.

Since $(d(u_{p-1}), d(u_{n-p+1})) = ((2p + 1), (2p - 1)) = 1$,

$(d(u_{p-1}), d(u_{3p})) = ((2p + 1), (2p)) = 1$, $(d(u_{3p}), d(u_{n-p+1})) = ((2p), (2p - 1)) = 1$

$(d(u_{p-1}), d(u_{3p}), d(u_{n-p+1})) = 1$, the relatively prime dominating set is $\{u_{p-1}, u_{3p}, u_{n-p+1}\}$.

$\therefore \gamma_{rpd}((CT(3, n))^p) = 3$ if $4p + 1 \leq n \leq 6p$ where $p \geq 2$.

Theorem 4.3. For any $CT(3, n)$ graph, $\gamma_{rpd}((CT(3, n))^p) = 0$ if $n \geq 6p + 1$ where $p \geq 2$.

Proof: Let G be a $(CT(3, n))^p$ graph. By theorem 4.2, $6p$ vertices are covered using u_p, u_{3p+1}, u_{n-p+1} vertices. But to cover the remaining vertices, we have to choose a vertex u_i of degree $2p$, where $3p + 2 \leq i \leq n - p$.

Then, $(d(u_{3p+1}), d(u_i)) = ((2p), (2p)) \neq 1$. Hence relatively prime dominating set does not exist. $\therefore \gamma_{rpd}((CT(3, n))^p) = 0$ if $n \geq 6p + 1$.

5 Python Program to Determine the Relatively Prime Domination Number on Power of Coconut Tree Graph

Based on the theorems in the previous sections, here is the python program to find the relatively prime domination number in power of coconut tree graph and to draw the graph.

The function $CT(m,n,p)$ takes three value m , n , p which denotes number of pendent edges, number of vertices of the path and power of the graph(like 2,...).

Function Input

```
import math
import networkx as nx
import matplotlib.pyplot as plt
def CT(m,n,p):
    #to draw the graph
    G = nx.star_graph(m)
    P = nx.path_graph(n-1)
    CT=nx.disjoint_union(G,P)
    CT.add_edge(0,m+1)
    #get the power of CT
    power_CT=nx.power(CT,p)
    F=power_CT
    nx.draw_spring(power_CT,with_labels=True)
    plt.show()
    #to find the relatively prime domination number from the theorems
    if p>1:
        if m==2:
            if ((p+1)<=n<=((4*p)+1)):
                print("Relatively prime domination number of the resultant graph is 2")
            elif (((4*p)+2)<=n<=((6*p)+1)):
                print("Relatively prime domination number of the resultant graph is 3")
            else:
                print("Relatively prime domination number of the resultant graph is 0")
        elif m==3:
            if ((p+1)<=n<=4*p):
                print("Relatively prime domination number of the resultant graph is 2")
            elif (((4*p)+1)<=n<=6*p):
                print("Relatively prime domination number of the resultant graph is 3")
            else:
                print("Relatively prime domination number of the resultant graph is 0")
    else:
        print("Give another graph with m = 2 or 3")
```

else:

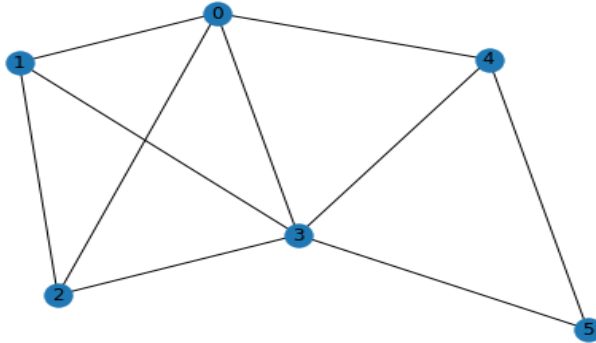
```
print("Give another value for p (p>1) to find the relatively prime domination number")
```

Output of few graphs

1. For the graph $(CT(2,4))^2$

Input: CT(2,4,2)

Output:

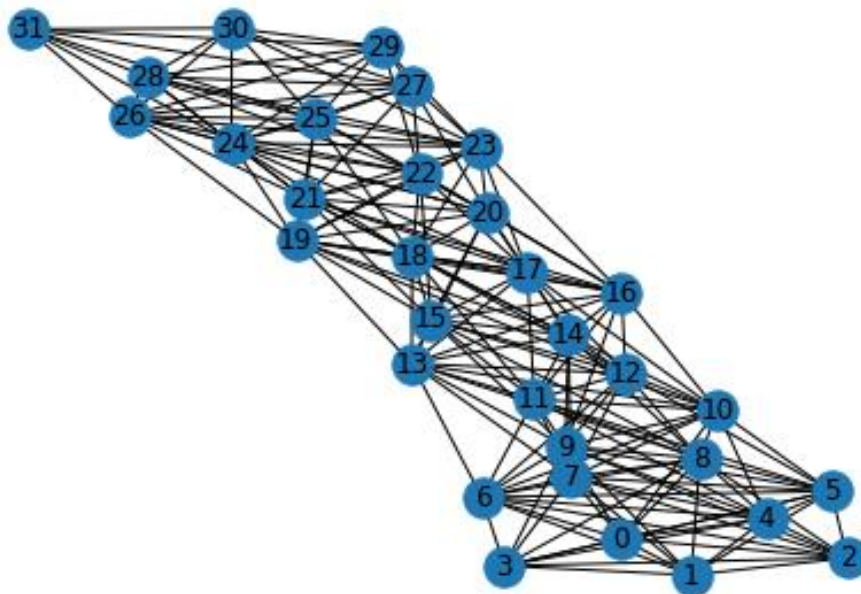


Relatively prime domination number of the resultant graph is 2

2. For the graph $(CT(3,29))^7$

Input: CT(3,29,7)

Output:



Relatively prime domination number of the resultant graph is 3

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Energy (Adjacency Energy) of a 3-uniform T_2 Hypergraph

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ABSTRACT

Let H be a 3-uniform T_2 Hypergraph of order $n \geq 5$. The adjacency matrix of the 3-uniform T_2 Hypergraph is defined by $A(H) = \begin{cases} |D_k \in D : (x_i, x_j) \subseteq D_k| & \text{if } x_i \neq x_j \\ 0 & \text{otherwise} \end{cases}$.

The adjacency energy of a 3-uniform T_2 Hypergraph is the sum of the absolute eigenvalues of its adjacency matrix. In H , $AE(H) \geq \Delta^2 + \delta^2 + \frac{1}{\Delta} + \frac{\delta}{\Delta^2}$, equality holds only if $n = 11$ in H .

Keywords: T_2 Hypergraph, 3-uniform T_2 Hypergraph, adjacency matrix, adjacency energy.

Subject Classification: 05C65

1 Introduction

The basic definitions and terminologies of a hypergraph are not given here; we refer it [1] and [2]. The concept of a Hypergraph was introduced by Berge in 1967. Later, different authors studied the same concept in [3] and [4]. Seena V and Raji Pilakkat were introduced to Hausdorff Hypergraph, T_0 Hypergraph and T_1 Hypergraph. Based on [5], [6] and [7] we introduced a new class of Hypergraph namely T_2 Hypergraph, 3-uniform T_2 Hypergraph and the parameter adjacency energy is studied for the same. Throughout this article, H is a simple connected 3-uniform T_2 Hypergraph with order n and size m . Here the order and size are the minimum numbers of vertices and edges used to define a 3-uniform T_2 Hypergraph. In $A(H)$, λ_1 is the largest eigenvalue and λ_n is the smallest eigenvalue. The following definitions and theorems are used in the sequel.

Definition 1.1. [5] A hypergraph $H = (X, D)$ is said to be a Hausdorff hypergraph if for any two distinct vertices u, v of X there exists hypergraph D_1 and D_2 such that $u \in D_1, v \in D_2$ and $D_1 \cap D_2 = \emptyset$.

Definition 1.2. [6] A hypergraph $H = (X, D)$ is said to be a T_0 Hypergraph if for any two distinct vertices u, v of X there exists a hyperedge containing one of them but not the other.

Definition 1.3. [7] A hypergraph $H = (X, D)$ is said to be a T_1 Hypergraph if for any two distinct vertices u, v of X there exists a hyperedge containing u but not v and another hyperedge containing v but not u .

Definition 1.4. [8] The adjacency matrix is the square matrix in which rows and columns are indexed by the vertices of H and where for all $u, v \in X, u \neq v, a_{uv} = |\{d \in D / u, v \in d\}|$ and $a_{uu} = 0$.

Definition 1.5. [8] The adjacency energy of a hypergraph is the sum of the eigenvalues of its adjacency matrix.

Definition 1.6. [9] A hypergraph $H = (X, D)$ is said to be a T_2 Hypergraph if for any three distinct vertices u, v and w in X there exists a hyperedge containing u and v but not w and another hyperedge containing w but not u and v .

Definition 1.7. A T_2 Hypergraph $H = (X, D)$ is said to be a 3-uniform T_2 Hypergraph if every hyperedge contains exactly three vertices.

2 Adjacency matrix and energy of a 3-uniform T_2 Hypergraph

In this section, we find the energy of a 3-uniform T_2 Hypergraph H, using adjacency matrix. Consider a 3-uniform T_2 Hypergraph H given in Figure 1 with 8 vertices and 7 edges.

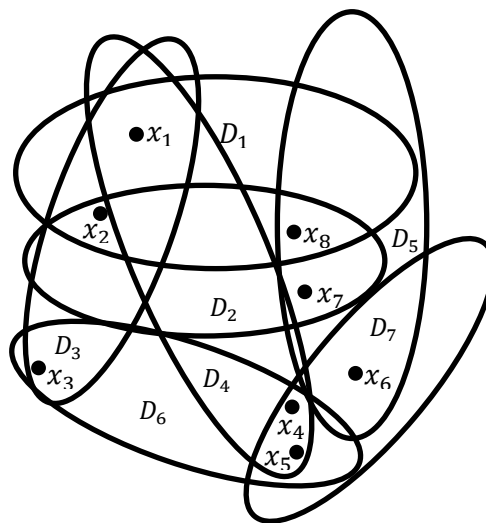


Figure 1: 3-uniform T_2 Hypergraph

The corresponding adjacency matrix of H is given by

$$A(H) = \begin{pmatrix} 0 & 1 & 0 & 0 & 0 & 1 & 2 & 2 \\ 1 & 0 & 1 & 1 & 0 & 0 & 0 & 1 \\ 0 & 1 & 0 & 3 & 1 & 0 & 0 & 1 \\ 0 & 1 & 3 & 0 & 1 & 0 & 0 & 1 \\ 0 & 0 & 1 & 1 & 0 & 1 & 1 & 0 \\ 1 & 0 & 0 & 0 & 1 & 0 & 2 & 0 \\ 2 & 0 & 0 & 0 & 1 & 2 & 0 & 1 \\ 2 & 1 & 1 & 1 & 0 & 0 & 1 & 0 \end{pmatrix}$$

The adjacency eigenvalues of A(H) are $\lambda = 5.42, 3.31, 1.43, -1.408, -2.298, -2.588, -3$.

Therefore, the adjacency energy $AE(H) = 20.314$.

Result 2.1. Let H be a 3-uniform T_2 Hypergraph with $n \geq 6$. Then the adjacency energy $AE(H) \geq \Delta^2 + \delta^2 + \frac{1}{\Delta} + \frac{\delta}{\Delta^2}$, equality holds for $n = 11$. The below table 1, shows the adjacency energy of a 3-uniform T_2 hypergraph for its order for $n \geq 6$.

Number of Vertices	AE(H)	$\Delta^2 + \delta^2 + \frac{1}{\Delta} + \frac{\delta}{\Delta^2}$
6	10.28	4.32
7	15.2	13.55
8	20.314	13.55
9	23.51	20.32
10	26.04	25.44
11	34.32	34.32
...
n	...	$\Delta^2 + \delta^2 + \frac{1}{\Delta} + \frac{\delta}{\Delta^2}$

Table 1: Adjacency energy of a 3-uniform T_2 Hypergraph

Clearly from Table 1, we can identify that, $AE(H) \geq \Delta^2 + \delta^2 + \frac{1}{\Delta} + \frac{\delta}{\Delta^2}$ for $n \geq 6$.

Result 2.2. Let H be a 3-uniform T_2 Hypergraph with $n \geq 5$. Then $[\lambda_1] = \Delta + \delta$. From the following Table 2, we can easily verify the result.

Number of Vertices	λ_1	$[\lambda_1]$	$\Delta + \delta$
5	5.78	6	6
6	4.09	4	4
7	4.87	5	5
8	5.42	6	6
9	6.15	6	6
10	6.68	7	7
11	8.27	8	8
...
n	...	...	$\Delta + \delta$

Table 2: Values of $\Delta + \delta$

Result 2.3. Let H be a 3-uniform T_2 Hypergraph with $n \geq 5$. Then $[\lambda_1] \geq \lfloor \sqrt{n} + k \rfloor$, equality holds for $n = 6$ and 7.

Number of Vertices	λ_1	$\sqrt{n} + k$	$[\lambda_1]$	$\lfloor \sqrt{n} + k \rfloor$
5	5.77	5.23	6	5
6	4.09	5.45	5	5
7	4.87	5.65	5	5
8	5.42	5.83	6	5
9	6.15	6	7	6
10	6.68	6.16	7	6
11	8.21	6.32	9	6
...
n	...	...	...	$\lfloor \sqrt{n} + k \rfloor$

Table 3: Values of $[\lambda_1]$

Result 2.4. Let H be a 3-uniform T_2 Hypergraph with $n \geq 5$. Then $\left[(\det A(H))^{\frac{1}{n}} \right] = \left\lceil \sqrt{\frac{n + \sqrt{\frac{k}{2}}}{k}} \right\rceil$

Number of Vertices	$(\det A(H))^{\frac{1}{n}}$	$\left\lceil (\det A(H))^{\frac{1}{n}} \right\rceil$	$\sqrt{\frac{n + \sqrt{\frac{k}{2}}}{k}}$	$\left\lceil \sqrt{\frac{n + \sqrt{\frac{k}{2}}}{k}} \right\rceil$
5	1.15	2	1.12	2
6	1.59	2	1.55	2
7	1.87	2	1.66	2
8	1.92	2	1.75	2
9	1.86	2	1.84	2
10	1.96	2	1.93	2
11	2.62	3	2.02	3
...
n	...	...	...	$\left\lceil \sqrt{\frac{n + \sqrt{\frac{k}{2}}}{k}} \right\rceil$

Table 4: Values of $(\det A(H))^{\frac{1}{n}}$

Theorem 2.5. Let H be a 3- uniform T_2 hypergraph with $n \geq 5$. Then $AE(H) < \frac{n(\Delta + \delta)^2}{\left\lceil \sqrt{\frac{n + \sqrt{\frac{k}{2}}}{k}} \right\rceil}$

Proof. We have, $[\lambda_1] > \left[(\det AE(H))^{\frac{1}{n}} \right] = \left\lceil \sqrt{\frac{n + \sqrt{\frac{k}{2}}}{k}} \right\rceil$

$[\lambda_1] \sum_{i=1}^n |\lambda_i| > \left[(\det AE(H))^{\frac{1}{n}} \right] \sum_{i=1}^n |\lambda_i| = \left\lceil \sqrt{\frac{n + \sqrt{\frac{k}{2}}}{k}} \right\rceil \sum_{i=1}^n |\lambda_i|$

Since, $[\lambda_1] = \Delta + \delta > |\lambda_i| \forall i = 2, 3, \dots, n$.

Therefore, $n[\lambda_1]^2 = n(\Delta + \delta)^2 > \left\lceil \sqrt{\frac{n + \sqrt{\frac{k}{2}}}{k}} \right\rceil AE(H)$

Hence, $AE(H) < \frac{n(\Delta + \delta)^2}{\left\lceil \sqrt{\frac{n + \sqrt{\frac{k}{2}}}{k}} \right\rceil}$

Illustration 2.6. Consider a 3-uniform T_2 hypergraph with $n = 8$. From the Table 1, Table 2

and Table 4, $AE(H) = 20.31$, $\Delta + \delta = 6$, $\left\lceil \sqrt{\frac{n+\sqrt{k}}{k}} \right\rceil = 2$. Here, $AE(H) = 20.31 < 144$

$$= \frac{n(\Delta+\delta)^2}{\left\lceil \sqrt{\frac{n+\sqrt{k}}{k}} \right\rceil^2} = \frac{8 \times 36}{2^2}.$$

Theorem 2.7. Let H be a 3- uniform T_2 hypergraph with $n \geq 5$. Then

$$AE(H) < \lceil \lambda_1 \rceil + \frac{(n-1)(\lceil \sqrt{n+k} \rceil)^2}{\left\lceil \sqrt{\frac{n+\sqrt{k}}{k}} \right\rceil}.$$

Proof. In H , $\lceil \lambda_1 \rceil \geq \lceil \sqrt{n+k} \rceil > \left[(detAE(H))^{\frac{1}{n}} \right] = \left\lceil \sqrt{\frac{n+\sqrt{k}}{k}} \right\rceil$

$$\lceil \sqrt{n+k} \rceil \sum_{i=2}^n |\lambda_i| > \left\lceil \sqrt{\frac{n+\sqrt{k}}{k}} \right\rceil \sum_{i=2}^n |\lambda_i|$$

Since $\left\lceil \sqrt{\frac{n+\sqrt{k}}{k}} \right\rceil > |\lambda_i| \forall i = 2, 3, \dots, n$.

$$(n-1) \left(\left\lceil \sqrt{\frac{n+\sqrt{k}}{k}} \right\rceil^2 \right) > \left\lceil \sqrt{\frac{n+\sqrt{k}}{k}} \right\rceil (AE(H) - \lceil \lambda_1 \rceil)$$

$$> \left\lceil \sqrt{\frac{n+\sqrt{k}}{k}} \right\rceil (AE(H) - \lceil \lambda_1 \rceil)$$

Hence, $AE(H) < \lceil \lambda_1 \rceil + \frac{(n-1)(\lceil \sqrt{n+k} \rceil)^2}{\left\lceil \sqrt{\frac{n+\sqrt{k}}{k}} \right\rceil}$.

Illustration 2.8. Consider a 3-uniform T_2 hypergraph with $n = 8$. From the Table 1, Table 3

and Table 4, $AE(H) = 20.31$, $\lceil \sqrt{n+k} \rceil = 5$, $|\lambda_1| = 6$, $\left\lceil \sqrt{\frac{n+\sqrt{k}}{k}} \right\rceil = 2$. Here, $AE(H) = 20.31 < 92.5 = \frac{7 \times 25}{2} + 5$. Hence the above theorem is verified.

3 Conclusion

In this article, we studied the adjacency matrix and its energy for a 3-uniform T_2 hypergraph. Also, we established the bounds of the adjacency energy of the 3-uniform T_2 hypergraph using various graph parameters.

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Domination Number in Edge Product Cluster Hypergraphs

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ABSTRACT

The study on Domination in Edge Product Cluster Hypergraph aims for a balance between the concepts of Domination and Edge Product in Cluster Hypergraphs. The cluster hypergraph $H = (V_X, E)$ is said to be an Edge Product Cluster Hypergraph if there exists an edge function $f: E \rightarrow I$ such that the edge function f and the corresponding edge product function F of f on V_X have the following conditions are $F(v) \in I$ for every $v \in V_X$ and if $f(e_1) \times f(e_2) \times \dots \times f(e_i) \in I$ for some edges $e_1, e_2, \dots, e_i \in E(H)$ then the edges e_1, e_2, \dots, e_i are all adjacent to some vertex set V_X . This article explores the concept of Domination in Edge Product Cluster Hypergraphs. Also, some theorems related to the concept of Domination in Edge product Cluster Hypergraphs have been discussed and demonstrated in this article.

Keywords: cluster hypergraph, edge product cluster hypergraph, unit edge product cluster hypergraph **AMS Subject Classification:** 05C65.

1 Introduction

The concept of domination in graphs originated with the Queens Problem in 1850. The idea of domination in graphs was introduced by G Claude Berge and Oystein Ore in 1962 [1], [2]. The notation of domination in hypergraphs was introduced by B.D. Acharya in 2007 and further studied by many authors. The domination in edge product hypergraphs was introduced by Kishor F Pawar and Megha M. Jadhav in 2021[3]. Several properties and results regarding an edge product hypergraph and unit edge product hypergraph have been studied. Some upper bound relations are derived. Also, the concept Domination in Edge Product Cluster Hypergraphs has been extended to prove some results.

The main results are proved by using the following theorems:

Theorem 1.1. [5] Let $H = (V_X, E)$ be a unit edge product cluster hypergraph with an edge $e \in E$. Then $f(e) = 1$ if and only if e must be adjacent to all the edges in H .

Theorem 1.2. [7] Suppose $H = (V_X, E)$ be a unit edge product cluster hypergraph with a unit edge. Then $\gamma(H) \leq |e| - k$, k represents the count of pendant vertices in e .

Theorem 1.3. [7] Consider the unit edge product cluster hypergraph $H = (V_X, E)$ with a unit edge e containing k pendant vertices. Suppose e_1, e_2, \dots, e_{m-1} be the non-unit edges in H . If $e_i \cap e_j = \emptyset$ in $H - e$ for all $1 \leq i \neq j \leq m - 1$, then $\gamma(H) = |e| - k$.

Theorem 1.4. [7] If $H = (V_X, E)$ is a unit edge product cluster hypergraph with a unit edge e , then e serves as a dominating set for H .

Theorem 1.5. [7] Consider the unit edge product cluster hypergraph $H = (V_X, E)$ with a unit edge e . Then any two distinct non-unit edges are non-adjacent if and only if $\gamma(H) = m - 1$.

2 Preliminaries

Definition 2.1 [4] Let X be a nonempty set and let V_X be a subset of $P(X)$ such that $V_X \neq \emptyset$ and $X \subset V_X$. Now E be a multi-set that includes elements from $P(P(X))$ such that (i) $E \neq \emptyset$ (ii) considering each element $e \in E$, there is at least one element $v \in V_X$ such that $v \in e$.

Then $H = (V_X, E)$ is called a *Cluster Hypergraph*, V_X is said to be a ~~vertex~~ set and E is known as a multi-hyper edge set.

Definition 2.2 The vertex degree $d_H(x)$ of x is the number of vertices adjacent to the vertex in the cluster hypergraphs H . The maximum vertex degree of a cluster hypergraph is denoted by $\Delta(H)$ and the minimum vertex degree of cluster hypergraph is denoted by $\delta(H)$.

Definition 2.3 A vertex v in a cluster hypergraph $H = (V_X, E)$, the set $N[v] = \{u \in V_X(H) : u \text{ is adjacent to } v\} \cup \{v\}$ is called the Closed Neighbourhood of v in H .

Definition 2.4 [5] Let $H = (V_X, E)$ be a cluster hypergraph with vertex set $V_X(H)$ and edge set $E(H)$. Let I be the set of positive integers such that $|E| = |I|$. Then any bijection $f: E \rightarrow I$ is called an Edge Function of the cluster hypergraph H .

Definition 2.5 [5] The function $F(v) = \prod \{f(e); \text{ edge } e \text{ incident to the vertex } v\}$ on $V_X(H)$ is said to be an Edge product Function of the edge function f .

Definition 2.6 [5] The cluster hypergraph $H = (V_X, E)$ is called an Edge Product Cluster Hypergraph if there is an edge function $f: E \rightarrow I$ such that the edge function f and the corresponding edge product function F of f on $V_X(H)$ have the following two conditions:

(i) $F(v) \in I$ for every $v \in V_X(H)$

(ii) if $f(e_1) \times f(e_2) \times \dots \times f(e_i) \in I$ for some edges $e_1, e_2, \dots, e_i \in E(H)$, then the edges e_1, e_2, \dots, e_i are all incident to some vertex $v \in V_X(H)$.

Definition 2.7 [5] Let $H = (V_X, E)$ be an edge product cluster hypergraph. Then H is said to be a Unit Edge Product Cluster Hypergraph if there exists an edge function $f: E \rightarrow I$ such that $1 \in I$.

Definition 2.8 [6] Let H be a cluster hypergraph. The minimum cardinality of a maximal strongly independent set in H is called the independent domination number and is denoted by $i(H)$.

3. Main Results

Definition 3.1[7] Let $H = (V_X, E)$ is an edge product cluster hypergraph. A Dominating Set of H is a collection of vertices $S \subseteq V_X(H)$ so that for each vertex $x \in V_X(H) - S$ there is an edge $e \in E(H)$ for which $x \in e, e \cap S \neq \emptyset$.

ie, for each vertex $x \in V_X(H) - S$ is adjacent to a vertex in S .

Example 3.1 Consider $H = (V_X, E)$ is an edge product cluster hypergraph where $V_X(H) = \{v_1, v_2, v_3, v_4, v_5, \dots, v_{18}\}$ and $E(H) = \{e_1, e_2, \dots, e_8\}$. The edges of H is defined as $e_1 = \{v_3, v_4, v_8, v_{12}, v_{16}\}$, $e_2 = \{v_1, v_3\}$, $e_3 = \{v_2, v_3\}$, $e_4 = \{v_4, v_5, v_6, v_7, \dots, v_{11}\}$, $e_5 = \{v_8, v_9, v_{10}, v_{11}\}$, $e_6 = \{v_{12}, v_{13}, v_{14}, v_{15}\}$, $e_7 = \{v_{16}, v_{17}, v_{18}\}$, $e_8 = \{v_{19}, v_{20}\}$. Now the edge function $f: E \rightarrow I$ is determined by $f(e_1) = 1, f(e_2) = 7, f(e_3) = 11, f(e_4) = 2, f(e_5) = 3, f(e_6) = 6, f(e_7) = 77, f(e_8) = 3$. The edge product function F of f is defined by $F(v_1) = 7, F(v_2) = 11, F(v_3) = 77, F(v_4) = 2, F(v_5) = F(v_6) = F(v_7) = 2, F(v_8) = F(v_9) = F(v_{10}) = F(v_{11}) = F(v_{12}) = F(v_{13}) = F(v_{14}) = F(v_{15}) = 6, F(v_{16}) = F(v_{17}) = F(v_{18}) = 77, F(v_{19}) = F(v_{20}) = 3$.

Here v_3 dominates $\{v_1, v_2\}$, v_4 dominates $\{v_5, v_6, v_7, \dots, v_{11}\}$, v_{12} dominates $\{v_{13}, v_{14}, v_{15}\}$, v_{16} dominates $\{v_{17}, v_{18}, v_{15}\}$ and v_{19} dominates v_{20} .

Therefore, $S = \{v_3, v_4, v_{12}, v_{16}, v_{19}\}$ with cardinality 5 dominates H . Hence, $\gamma(H) = 5$.

Theorem 3.2 Let $H = (V_X, E)$ represents a unit edge product cluster hypergraph with a unit edge e containing k pendant vertices. If the set of edges e_1, e_2, \dots, e_{m-1} serve as the non-unit edges in H . Then $\gamma(H) = |e| - k$ iff $e_i \not\subseteq e_j$ for all $1 \leq i \neq j \leq m - 1$ in $H - e$.

Proof Let $H = (V_X, E)$ represents a unit edge product cluster hypergraph with a unit edge e containing k pendant vertices. Let e_1, e_2, \dots, e_{m-1} serves as the non-unit edges in H .

First assume that $e_i \not\subseteq e_j$ for all $1 \leq i \neq j \leq m - 1$ in $H - e$. Let $e_i' = e_i - e$ and $e_j' = e_j - e$. Then clearly, $e_i' \not\subseteq e_j'$ for all $1 \leq i \neq j \leq m - 1$ in H .

If $e_i \cap e_j = \emptyset$ in $H - e$, then $\gamma(H) = |e| - k$ (3).

Suppose $e_i \cap e_j = \emptyset$. If $e_i' = \emptyset$, then $e_i \cap e_j$ contains only the vertices in e . The vertices in e dominates the vertices in e_i and e_j . In e the vertices v_1, v_2, \dots, v_{m-1} must dominate all the other vertices contained in the edges e_1, e_2, \dots, e_{m-1} . Clearly, the non-pendant vertices in \bar{e} is dominated by pendant vertices in e . So, there are minimum $|e| - k$ number of vertices required to dominate the unit edge product cluster hypergraphs H . So $\gamma(H) \geq |e| - k$. Thus, by Theorem 1.2, it is concluded that $\gamma(H) = |e| - k$.

Similarly, to prove for $e_j' = \emptyset$. Assume that, $e_i' \neq \emptyset$ and $e_j' \neq \emptyset$. Since $e_i' \not\subseteq e_j'$ for all $1 \leq i \neq j \leq m - 1$ all the vertices in e_i' is not dominated by the vertices in e_j' . To dominate the vertices in e_i' choose the vertex v_i . choose the vertex v_j , to dominate the vertices in e_j' for all $i \neq j$. Therefore, there exists at least $|e| - k$ vertices in H in order to dominate all the vertices in H , and so $\gamma(H) \geq |e| - k$. By Theorem 1.2, it can be concluded that $\gamma(H) = |e| - k$.

Conversely, suppose that $\gamma(H) = |e| - k$. Let u_1, u_2, \dots, u_k be the collection of all pendant vertices in H . Let $S = e - \{u_1, u_2, \dots, u_k\}$ dominates H . Let e_i and e_j be any two non-unit distinct edges in H . To prove $e_i \not\subseteq e_j$ for all $1 \leq i \neq j \leq m - 1$. Suppose there exists p, l with $1 \leq p < l \leq m - 1$ such that $e_p \subseteq e_l$. Then, the intersection of e_p and e_l is e_l .

Let $x \in e_i \cap e$. Since H serves as a unit edge product cluster hypergraph for every $e_i \in E$, choosing a vertex $x \in e_i \cap e$ for $1 \leq i \leq m - 1$. The vertices inside the cluster vertices are dominated by the cluster vertices. Obviously, these vertices must be in the intersection of e_i and the unit edge e . If x_1, x_2, \dots, x_s be the distinct vertices incident with the edges e_1, e_2, \dots, e_{m-1} and different from the pendant vertices u_1, u_2, \dots, u_k together with x forms a dominating set H with cardinality $s + 1$ is equal to $|e| - k - 1 < |e| - k$ which leads to a contradiction. Thus, our assumption is wrong. Hence, $e_i \not\subseteq e_j$ for all non-unit edges with $1 \leq i \neq j \leq m - 1$.

Theorem 3.3 Let $H = (V_X, E)$ represents a unit edge product cluster hypergraph. Then any minimum dominating set of H must contain vertices from the unit edge.

Proof. Let $H = (V_X, E)$ represents a unit edge product cluster hypergraph with a unit edge e . Let S dominates H . Since H serves a unit edge product cluster hypergraph, by the Theorem 1.1, there exists at least one edge other than e which is adjacent only to e .

Let m be the edge in H which is adjacent to e . Then, there is a vertex $y \in S$ such that x is adjacent to y , for any $x \in e$. Therefore, y belongs to either the intersection of e and m or the pendant vertex in e . Hence, S must contain a vertex from the unit edge e .

Theorem 3.4 Let $H = (V_X, E)$ represents a unit edge product cluster hypergraph with $\gamma(H) + \Delta(H) = |V_X(H)|$ and consider x as a vertex of maximum degree in H . Then, the unit edge e contains at least $|H - N[x]|$ number of vertices.

Proof. Let $H = (V_X, E)$ represents a unit edge product cluster hypergraph with $\gamma(H) + \Delta(H) = |V_X(H)|$. Consider x be a vertex of maximum degree in H and e be a unit edge in H . It is to be verified that, e contains at least $|H - N[x]|$ number of vertices. Suppose m be an edge that includes the vertex $y \in H - N[x]$. Since H serves as a unit edge product cluster hypergraph, m cannot be a unit edge in H . By the Theorem 1.4, m must be adjacent to e in H . Thus, there is a vertex $u \in e$ such that u is adjacent to y , which belongs to the intersection of the unit edge and the edge containing the vertex y , for every vertex $y \in H - N[x]$. To show that, $|e| \geq |H - N[x]|$. Suppose on contrary, assume that $|e| < |H - N[x]|$. This shows that there doesn't exist a unique vertex $u \in e$ with $y \in H - N[x]$.

Let $x_1, x_2 \in H - N[x]$ there exists a single vertex $u \in e$ with $S = \{\{x, u\} \cup (V - [N[x] \cup (N(u) \cap (V - N[x]))])\}$ dominates H with cardinality $2 + |V_X(H)| - \Delta(H) - 1 - 2 = |V_X(H)| - \Delta(H) - 1$. It follows that $\gamma(H) + \Delta(H) = |V_X(H)| - 1$, which is a contradiction. Hence, the unit edge e contains at least $|H - N[x]|$ number of vertices.

Theorem 3.5. Let $H = (V_X, E)$ represents a unit edge product cluster hypergraph with $i(H) + \Delta(H) = |V_X(H)|$ and consider x as a vertex of maximum degree in H . Then H contains at least $|V_X(H) - N[x]|$ number of non-unit edges in H .

Proof. Let $H = (V_X, E)$ be a unit edge product cluster hypergraph with $i(H) + \Delta(H) = |V_X(H)|$ and let x be a vertex of maximum degree in H . Let e be a unit edge in H . Suppose H contains at most $|V_X(H) - N[x]| - 1$ number of non-unit edges in H . Since H is a unit edge product cluster hypergraph, any edge containing the vertex $y \in V_X(H) - N[x]$ is adjacent to the edge e . Clearly, there exists two vertices u and v in $V_X(H) - N[x]$ with u and v are adjacent. Therefore, the magnitude of any strongly independent dominating set of $V_X(H) - N[x]$ is at most $|V_X(H) - N[x]| - 1$.

Thus, $i(H) \leq |V_X(H) - N[x]| - 1 + |x| = |V_X(H)| - \Delta(H) - 1$. That is, $i(H) + \Delta(H) \leq |V_X(H)| - 1$ implies that $i(H) + \Delta(H) < |V_X(H)|$, which is a contradiction. Hence our assumption is wrong. Therefore, H contains minimum $|V_X(H) - N[x]|$ number of non-unit edges in H .

Theorem 3.6 Let $H = (V_X, E)$ represents a unit edge product cluster hypergraph with a unit edge e containing at least one pendant vertex. If $\gamma(H) = m - 1$, then each dominating set contains at least one vertex from e .

Proof. Let $H = (V_X, E)$ represents a unit edge product cluster hypergraph with a unit edge e containing at least one pendant vertex. Assume $\gamma(H) = m - 1$. Let S be any dominating set in H . To prove S contains at least one vertex from e . Suppose S contains no elements from e . Since $\gamma(H) = m - 1$, S contains at most $m - 1$ number of vertices. Since H contains m edges and each non-unit edges are adjacent to e and S contains no vertex from e , so that S must contain vertices from the non-unit edges. To dominate the pendant vertex in e and the non-unit vertices in H , there must be any two non-unit edges are adjacent as it is $|S| \leq m - 1$. By a Theorem 1.5, $\gamma(H) \neq m - 1$, this results in a contradiction. So, our assumption is incorrect. Therefore, S contains at least one vertex from the unit edge e .

Theorem 3.7 Let $H = (V_X, E)$ represents a unit edge product cluster hypergraph of size $m \geq 3$. If e is a unit edge of H then,

$$(i) 2 \leq \gamma(H) + \gamma(\bar{H}) \leq |e| + 1.$$

$$(ii) 1 \leq \gamma(H) \cdot \gamma(\bar{H}) \leq |e|.$$

Proof. For any unit edge product cluster hypergraph H is a cluster hypergraph. Then $\gamma(H) \geq 1$. Also H is connected, the complement \bar{H} is also a cluster hypergraph and $\gamma(\bar{H}) \geq 1$. This suggests that $\gamma(H) + \gamma(\bar{H}) \geq 2$ and $\gamma(H) \cdot \gamma(\bar{H}) \geq 1$. Thus, it proves the lower bound.

In order to prove for the upper bound, consider that H is a cluster hypergraph, then the unit edge forms a dominating set in H . Therefore, $\gamma(H) \leq |e|$. Every maximal edge in H is adjacent only to e . Let m be the edge in H , which is adjacent only to e . Let f be any edge in H . So, the edges m and f are two independent edges in H . Consider the vertex $x \in V_X(H)/m \cup f$, then for any other vertex $y \in V_X(H)$ such that the vertex x is adjacent to y in \bar{H} . Thus $\gamma(\bar{H}) \leq 1$. Hence, it follows that $\gamma(H) + \gamma(\bar{H}) \leq |e| + 1$ and $\gamma(H) \cdot \gamma(\bar{H}) \leq |e|$.

4. Conclusion

In this article, the concept Domination in Edge Product Cluster Hypergraph and Unit Edge Product Cluster Hypergraph has been applied and also, the same concept is extended to prove some theorems related to the Domination Number in Edge Product Cluster Hypergraph, Unit Edge Product Cluster Hypergraph.

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Growth Kinematics of Copper Doped L-Alanine Single Crystal for Optical Window

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ABSTRACT

The pH-dependent structural transformations of L-Alanine, specifically in cationic, zwitterionic, and anionic forms, hold significant relevance for applications across biochemistry and materials science. At different pH levels, L-Alanine exhibits distinct configurations: cationic at pH 1, zwitterionic at pH 6, and anionic at pH 13. These forms influence intermolecular interactions, solubility, and bonding, crucial for crystal growth and metal ion interactions. This study investigates the solubility, crystallographic parameters, Fourier Transform Infrared (FTIR) spectral analysis, and UV-Visible spectroscopy of copper-doped L-Alanine crystals, analyzing their structural and optical properties at varying copper concentrations.

Keywords: Copper, crystal growth, L-Alanine, organometallic, Solubility

1. Introduction

Conventional crystal growth techniques often enhance specific empirical properties, leading to optimized product quality, greater application efficiency, cost-effectiveness, and improved usability. Among the essential characteristics for developing high-grade crystals are physicochemical and Nonlinear Optical (NLO) properties, which are crucial for use in devices such as light emitters, dosimeters, photonics, electro-optical components, and semiconductors [1]. Current research focuses on producing nonlinear photonic crystals with properties like a lower UV cutoff, broader transmittance range, greater nonlinearity, higher damage threshold, and suitable thermal and mechanical properties. To achieve these, pure organic and inorganic materials have been combined, with recent emphasis on organic crystals due to their lower cost, faster nonlinear response across frequencies, and higher optical damage threshold [2, 3]. However, organic crystals are limited by volatility, low thermal stability, and weak mechanical properties [4]. To address these limitations, organometallic crystals, introduced in the 1960s for optoelectronic applications, combine the advantages of organic and inorganic crystals. These materials are created by integrating inorganic distorted polyhedrons with asymmetric organic molecules [1]. This design imparts

high optical nonlinearity, mechanical flexibility, temporal and thermal stability, and enhanced transmittance compared to purely organic or inorganic crystals. Additionally, organometallic materials offer unique metal-ligand and intra-ligand charge transfer, making them highly suitable for NLO applications [5].

Synthesis and characterization of amino acid crystal was found in the report with different solvents such as methanol and ethanol and the synthesis process of slow cooling method. In this paper we report the growth of copper doped L-Alanine single crystal at the room temperature and analyzed the structural and optical behavior. It provides the method of the synthesis, properties, growth parameters, and significant characteristics of copper doped amino acid crystals, emphasis on their NLO attributes.

2. Experimental Details

2.1. Synthesis of Copper doped L-Alanine single crystal

The organometallic copper admixed L-Alanine amino acid crystals were grown in variable stoichiometric compositions by the method of slow evaporation crystal growth technique. Generally, the crystal growth techniques consist of a two steps process in which the first step is the synthesis and second step is the growth process. For the synthesis process of copper doped L-Alanine crystal, copper acetate and L-Alanine solutes and deionized water are utilized as a solvent. One molar quantity of L-Alanine was completely dissolved in a 20 ml of deionized water. Then 0.2, 0.4 and 0.6 molar percentages of copper acetate solutes were dissolved separately into the one molar solution of the L-Alanine. The complete mixture solution is heated at a constant temperature of 40°C until the phase transition from the liquid solution to the solid mixture. After heating the same quantity of solvent was added and completely stirred well for about three hours to obtain the saturated solution.

The growth process involves the filtration of the saturated solution with the filter paper. The resultant solution was taken in a beaker and covered with a plastic cover. The cover consists of fine holes and placed in an atmosphere free from the dust. Thus, the solution was allowed for the solvent evaporation as a result nuclei of crystal after the ninth day and good quality of copper doped L-alanine single crystals were harvested within the period of a month.

2.2. Characterization

Parameters like pH and solubility affect the growth of the crystals. As prepared copper doped L-Alanine single crystals of dimension 10×5×4 mm³ were subjected to the characterization such as single crystal X-ray Diffraction (XRD), linear and non-linear optical studies and Fourier Transform Infrared (FTIR) studies. Single crystal X-ray diffraction

analysis was carried out using a Bruker AXS diffractometer with MoK α ($\lambda=0.7170$ Å) radiation to identify the lattice parameters. The optical absorbance spectrum of the copper doped L-Alanine crystal was recorded in the spectral range between 200-1200 nm using the ELICO model UV spectrophotometer.

3. Results and Discussion

3.1. pH Analysis

The amino acid L-Alanine exhibits different structure depending on the pH. Understanding the influence of pH and their interactions is necessary for different applications including material science and biochemistry. Generally L-Alanine forms the solid structure at three different forms namely cationic form at the pH of 1, secondly zwitterionic form at pH 6 and anionic form of pH 13. At high acidic nature, L-Alanine is in the cationic form $[\text{CH}_3\text{CH}(\text{NH})^{3+}\text{COOH}]$, whereas the intermolecular hydrogen bonds lead to the dimer's formation. In zwitterionic form at neutral pH, L-Alanine experiences zwitterionic form $[\text{CH}_3\text{CH}(\text{NH})^{3+}\text{COO}^-]$, the inter hydrogen bond between NH^{3+} and COO^- dominates. In the anionic form at higher acidic environments, L-Alanine experiences $[\text{CH}_3\text{CH}(\text{NH}_2)\text{COO}^-]$, there is a strong interaction between and metal ions [6]. Since deionized water is used as a solvent for the growth process, neutral pH has been considered as a best value, in which the zwitterionic form of L-Alanine decreased the affinity of the copper metal due to strong NH^{3+} -- COO^- intermolecular hydrogen bond that prevail over the interaction with copper.

3.2 Solubility Analysis

The crystal growth rate is influenced by solubility and temperature, making it essential to test the compound's solubility in various solvents to optimize growth parameters [2, 3]. To assess the solubility of the L-Alanine with total mass was dissolved in a fixed volume of distilled water. This solution was placed in a 250 ml glass beaker equipped with a temperature probe and a glass stirrer. The solution was stirred and heated to 35 °C above the temperature for thorough mixing, once equilibrium was achieved, liquid samples were drawn using a 10 ml plastic syringe. Approximately 5 ml of each solution was filtered through a 0.20 μm syringe filter and transferred to an empty vial. This vial was then weighed and dried at 40 °C in an oven. Finally, the solute amount was calculated by subtracting the initial weight of the vial from the weight after drying. The evaporated water amount was determined by comparing the vial's weight before and after evaporation. Three samples were collected at each saturation temperature to ensure reproducibility, and the gravimetric method was used to measure solute concentration in the solution tabulated in table 1.

Table 1. Solubility of L-Alanine

Temperature (°C)	Concentration of solute (gm/10ml of water)
35	6
40	11
50	16
55	18
60	21

3.3 Structural Analysis

Single crystal X-Ray diffraction studies had been carried out for the copper doped L-Alanine crystal. The cell parameters and crystal structure of the crystals were determined. Mostly, the single crystal XRD was used to evaluate the parameters like crystal structure, space group, unit cell parameters and cell volume (V). Table 2 summarizes the crystallographic parameters for copper doped L-Alanine crystal. The reported unit cell parameters vary slightly between different depends for the same compound. The single crystal X-Ray diffraction studies confirm the orthorhombic crystal system with the space group of P2₁2₁2 the same was identified in the literature by Rathnakumar et.al [7]. Using the single crystal XRD data, the miller indices values are generate using the index software package, tabulated in table 3.

Table 2. Unit Cell parameters of copper doped L-Alanine single crystal

Crystal	Lattice parameters (Å)	Crystallographic axes (degree)	Volume (Å) ³
0.2 mole % copper doped L-Alanine	a= 5.83, b=6.04, c=12.33	$\alpha=90, \beta=90, \gamma=90$	434
0.4 mole % Copper doped L-Alanine	a= 5.89, b=6.35, c=12.53	$\alpha=90, \beta=90, \gamma=90$	467
0.6 mole % Copper doped L-Alanine	a= 5.95, b=6.46, c=12.89	$\alpha=90, \beta=90, \gamma=90$	493

Table 3. Miller Indices for the copper acetate doped L- Alanine crystal

h	k	l	d-spacing (Å)	θ (degree)	h	k	l	d-spacing (Å)	θ (degree)
2	3	0	1.6566	12.362	3	4	1	1.1868	7.387
2	3	1	1.6419	12.475	4	3	0	1.1806	17.481

2	3	2	1.5999	12.808	2	4	5	1.1779	17.522
2	3	3	1.5365	13.345	4	3	1	1.1752	17.564
2	3	4	1.4592	14.066	3	4	2	1.1707	17.635
3	3	0	1.3982	14.693	4	3	2	1.1595	17.810
3	3	1	1.3893	14.789	3	4	3	1.1451	18.041
2	3	5	1.3751	14.946	4	3	3	1.1347	18.213
3	3	2	1.3636	15.075	2	5	0	1.1160	18.530
2	4	0	1.3408	15.338	3	4	4	1.1121	18.597
2	4	1	1.3329	15.430	2	5	1	1.1114	18.608
3	3	3	1.3237	15.540	4	3	4	1.1025	18.764
2	4	2	1.3102	15.705	2	5	2	1.0981	18.842
2	4	3	1.2747	16.154	2	5	3	1.0770	19.226
3	3	4	1.2734	16.172	3	4	5	1.0735	19.292
2	4	4	1.2295	16.765	4	3	5	1.0649	19.454
3	3	5	1.2163	16.952	2	5	4	1.0493	19.754
3	3	5	1.2163	16.952	4	4	0	1.0487	19.767
3	4	0	1.1924	17.304	4	4	1	1.0449	20.841

3.4 Fourier transforms infrared spectral analysis

Fourier Transform Infrared (FTIR) spectroscopy is a key analytical technique used to identify functional groups, ligand coordination, and quantify bending and stretching vibration modes of molecules. In this process, IR radiation passes through the sample, and the absorption and transmission spectra create a unique molecular fingerprint of the sample. FTIR analysis was performed on powdered crystals of copper doped L-Alanine to verify the presence of functional groups. The spectra were recorded across the 400 to 4000 cm^{-1} range. The FTIR spectra of 0.2, 0.4 and 0.6 mole% of copper doped L-Alanine crystals were depicted in the fig. 1-3 and the band assignments are tabulated in the table 4.

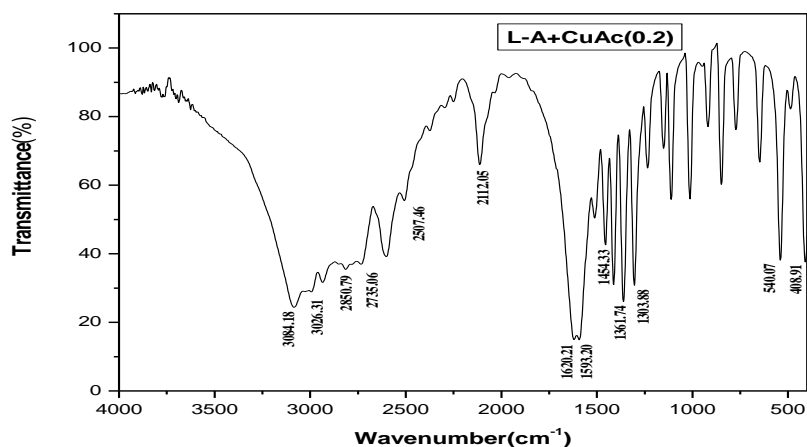


Fig. 1. FTIR Spectra of 0.2 mole % copper doped L-Alanine

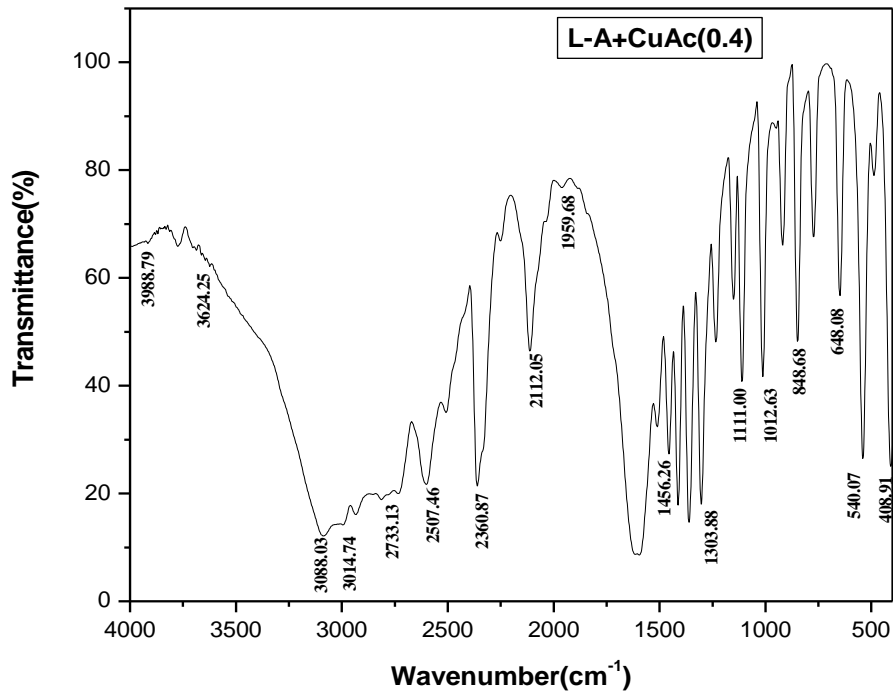


Fig. 2. FTIR Spectra of 0.4 mole % copper doped L-Alanine

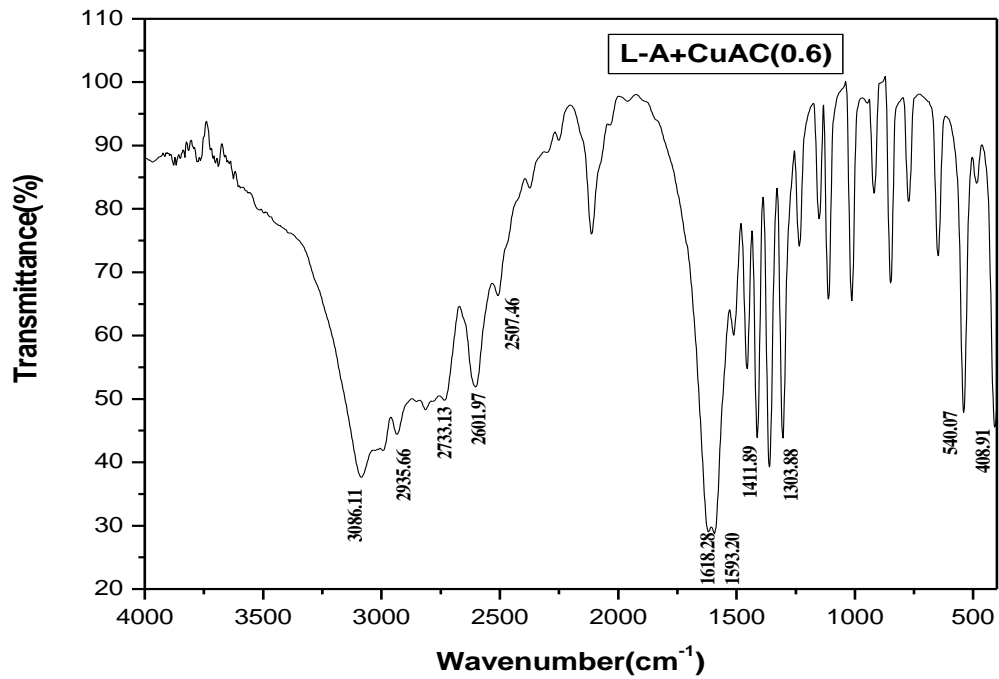


Fig. 3. FTIR spectra of 0.6 mole % copper doped L-Alanine

Table 4. Bond Assignments of copper doped L-Alanine crystal

L-Alanine + 0.2 mol % CuAc	L-Alanine + 0.4 mol % CuAc	L-Alanine + 0.6 mol % CuAc	Band Assignments
3084.4	3088.03	3086.11	O-H Stretching mode
2814.14	2814.14	2814.14	N-H stretching
2781.35	2753.13	-	C-N stretching
2601.97	2601.97	2601.97	C-N stretching
2507.46	2507.46	2507.46	C-N stretching
2112.05	2112.05	-	C-N stretching
1512.19	1595.13	1593.20	C-N bending
1620.21	1614.32	-	CH ₃ asymmetric
1361.74	1361.74	1303.88	CH ₃ asymmetric
1074	1012	1031	CH ₃ Rocking

Numerous studies reported that the OH stretching vibration in FTIR spectrum of L-Alanine doped copper acetate often lies around 3400 cm^{-1} is assigned to the symmetric stretching mode of water molecules but in copper acetate doped L-Alanine the broad band observed at 3084.4 , 3088.03 and 3086.11 cm^{-1} in the 0.2, 0.4 and 0.6 mole percentage of copper. N-H stretching vibrations lies due to the small peak identified around 2900 cm^{-1} , this bond arises due to the NH_2 group present in the amino acids [8]. The narrow peaks between the wavelength $2100\text{-}2800\text{ cm}^{-1}$ reveals the CN bond stretching. Additional peaks located near 1593.20 cm^{-1} is assigned for C-N bending. Strong absorption in the range between 1300 to 1700 cm^{-1} are assigned as a CH_3 asymmetric vibration of L-Alanine molecule and rocking vibrations are identified around 1000 cm^{-1} [9]. Other weak absorption peaks at 1040 cm^{-1} are attributed to C=C stretching, between 900 and 950 cm^{-1} are due to the C=C stretching vibration [10]. Sharp absorption near 600 and 500 cm^{-1} are successively assigned as OCO symmetric bending and NH_3 torsional vibration of L-Alanine copper acetate respectively.

3.5 UV Visible Spectroscopy

UV-Visible Spectroscopy measures the optical absorption of light in the UV and visible regions when it passes through the prepared copper acetate doped L-Alanine crystal and the absorbance spectra is shown in graph fig.4 to 6. The ultraviolet light absorbed by the crystal gives information about the transparency, reflectance band gap windows which are very essential in many optical electronic applications.

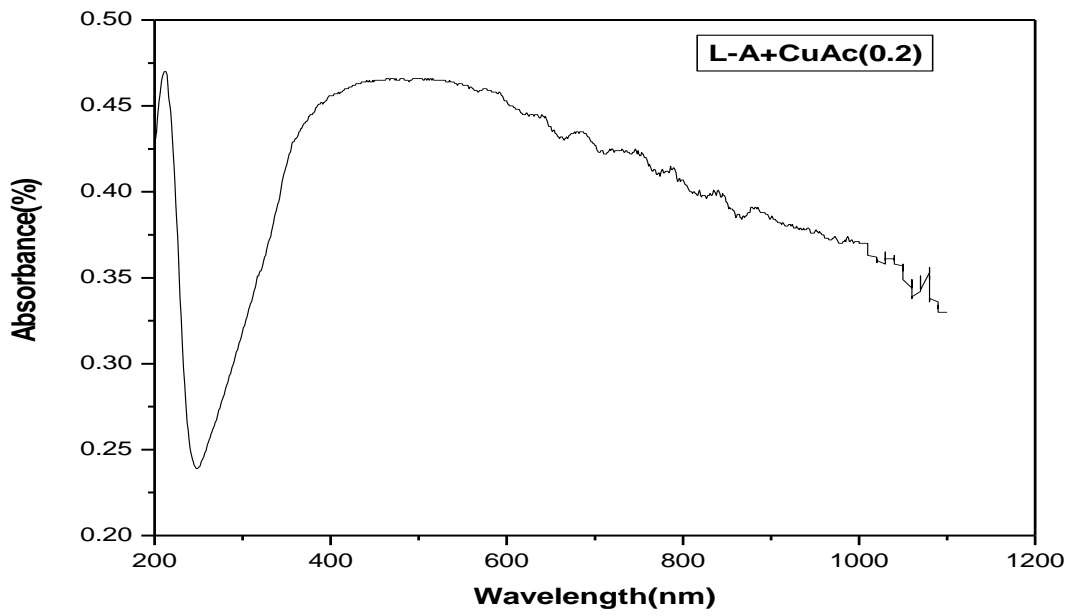


Fig. 4. Absorbance of 0.2 mole % copper doped L-Alanine crystal

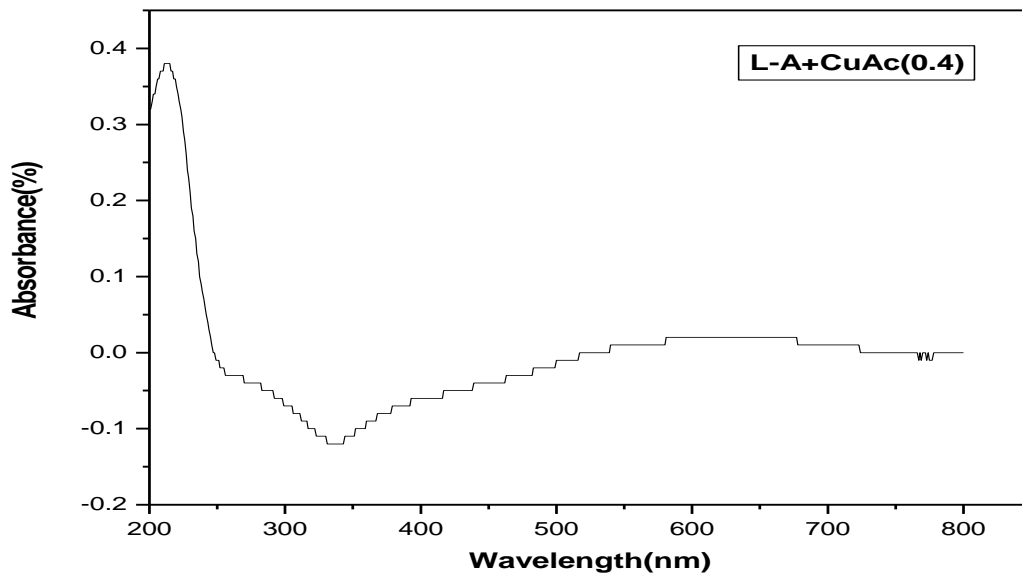


Fig. 5. Absorbance of 0.4 mole % copper doped L-Alanine crystal

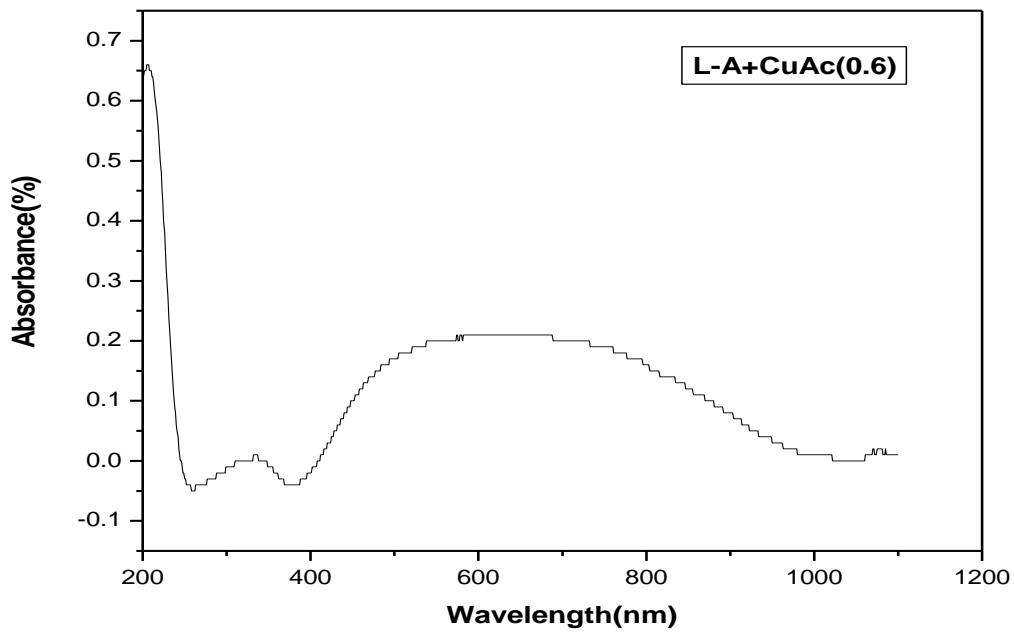


Fig. 6. Absorbance 0.6 mole % of copper doped L-Alanine crystal

The graph shows 0.2 mole % of copper doped L-Alanine exhibits maximum peaks at 210 nm, 0.4 exhibits maximum peak at 214 nm and 0.6 exhibits maximum peak at 208 nm. Reflectance is a measure of the amount of light reflected after it passes through the copper doped L-Alanine crystal in ultraviolet and visible wavelengths. The reflectance spectrum of copper doped L-Alanine crystal is depicted in fig.7 to 9.

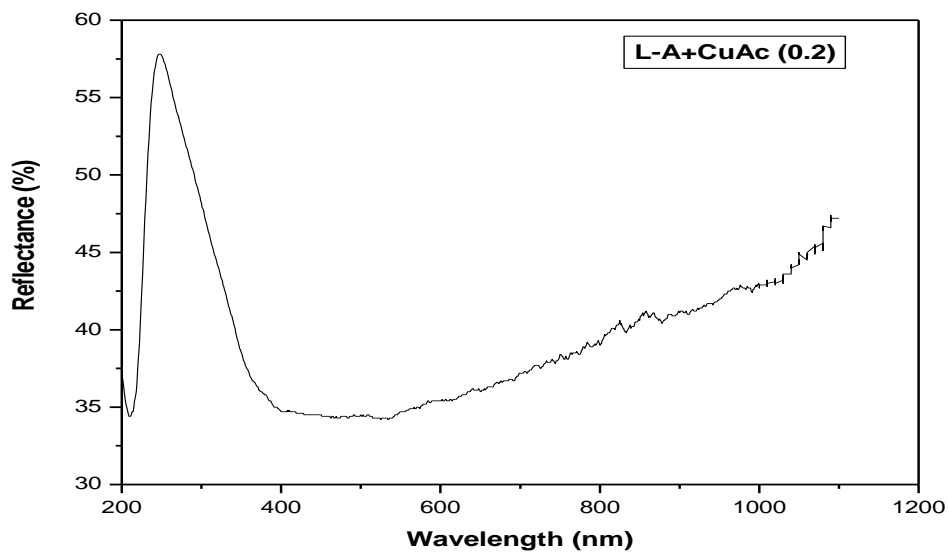


Fig. 7. Reflectance of 0.2 mole % copper doped L-Alanine

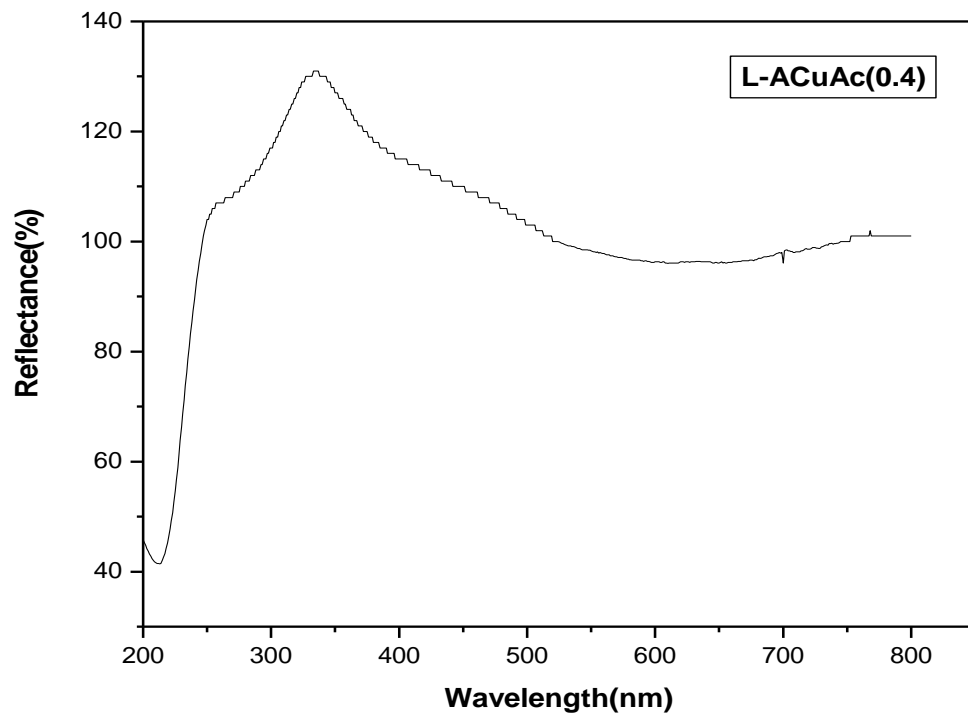


Fig. 8. Reflectance of 0.4 mole % copper doped L-Alanine

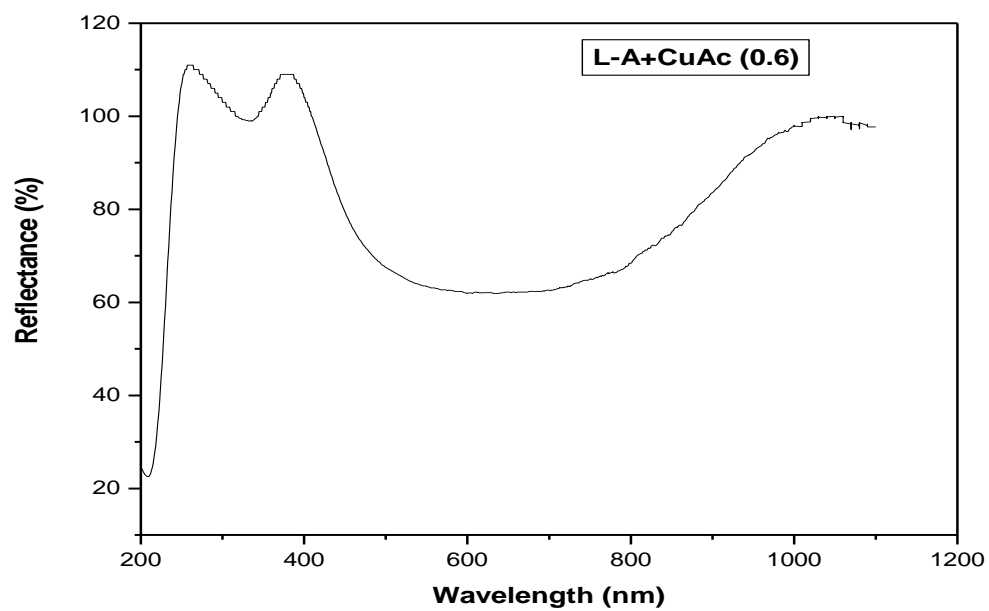


Fig. 9. Reflectance of 0.6 mole % copper doped L-Alanine

Photon energy is the energy carried by a single Photon is calculated using the relation; where h is the Planck's constant, c is the velocity of light, E is photon energy, λ is the photons wavelength. The calculated optical parameters are tabulated in table 5.

$$E_g = hc/\lambda$$

Table 5. Optical data

Crystal	Maximum Absorbance (%)	Maximum Transmittance (%)	Maximum Reflectance	Photon Energy(eV)
0.2 mole % of copper L-Alanine single crystal	0.4699	99.05	57.58	5.25
0.4 mole % of copper L-Alanine single crystal	0.374	99.11	130.68	5.24
0.6 mole % of copper L-Alanine single crystal	0.6553	99.12	131.138	5.41

The UV cutoff wavelength of all the three prepared crystals occurs at 250 nm and showed nearly 99% in the entire visible region, it was concluded that the crystals are effective for the NLO application [11]. However, the optical band energy suggested that the copper doped L-Alanine crystal belongs to the semiconductor nature suitable for the optical window.

4. Conclusion

This work details the behavior and structural changes of L-Alanine with respect to pH, highlighting its solid states as a cation, zwitterion, and anion. Experimental solubility testing in water provided insights into optimal growth conditions at varying temperatures. Crystallographic data, obtained via single crystal X-Ray diffraction, confirm an orthorhombic structure in copper-doped L-Alanine, while FTIR spectroscopy reveals functional group vibrations and bonding specifics in the doped crystals. UV-Visible spectroscopy indicates light absorbance characteristics of the crystals, which vary with copper concentration. These findings underscore the critical role of pH and copper doping in modifying the structural and optical properties of L-Alanine, with implications for its applications in optical electronics and material science.

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Experimental Investigation on Sodium Acetate Treated Luffa Fibre and its Characterization

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ABSTRACT

As environmental concerns grow, natural plant fibers are becoming popular alternatives to synthetic fibers. Among these, Luffa fibers are notable for their widespread availability. These fibers have unique ligno-cellulosic properties, making them desirable. One key advantage of natural fibers is their light weight and non-toxic impact on the environment. Luffa fibers are especially valued for their elasticity. Being biodegradable, they are highly recommended for sustainable uses. This study focuses on understanding the structural, thermal, and physical properties of Luffa fibers. Basic properties like fiber diameter and density were carefully measured. The fibers were treated with alkali and sodium acetate at room temperature.

Keywords: FTIR, SEM, XRD

1. Introduction

As global environmental consciousness continues to ascend, natural plant fibers are increasingly recognized as noble alternatives to synthetic counterparts. With their inherent sustainability, biodegradability, and favorable properties, these fibers are poised to supplant synthetic fibers across diverse applications [1]. The esteemed virtues of plant fibers – spanning environmental, economic, and functional domains – have garnered them growing acclaim across industries, from textiles to advanced composite materials of natural plant fibers as reinforcement in composite materials has garnered significant interest among researchers and industry leaders alike. These fibers may be deftly incorporated into various matrices, such as polymers, to forge eco-friendly, lightweight, and often economically advantageous composite structures [2]. Distinct their lower density in comparison to synthetic fibers such as glass or carbon, plant fiber composites deliver a lighter composition. This attribute proves particularly advantageous in sectors such as automotive and aerospace, where weight reduction aligns with greater fuel efficiency. Further enhancing their appeal, many plant fibers offer high tensile strength and commendable flexibility. As industries pivot

towards materials that align with ecological priorities, these natural fibers are emerging as worthy successors to conventional structural materials, including glass and carbon fiber composites [3]. Their application spans sectors of paramount importance, including automotive, construction, aerospace, and renewable energy, affirming their place in the noble pursuit of a sustainable future [4].

2. Materials and Methods

Luffa fibers have a unique, spongy texture and are known for being environmentally friendly. To prepare the fibers, start by harvesting mature Luffa fruits. Let them dry, then separate the fibers and clean them to remove impurities. Gather the amount of fiber needed, and dry it for 10 days. After drying, soak the fibers in a 0.1 M alkali solution for 20 minutes, then allow them to dry again in the shade for 5 days. Fig 1 shows the entire chemical processing of Luffa fibre.



Fig. 1. Sodium acetate treatment of Luffa fibre

3. Results and Discussion

3.1. PXRD Analysis

The fibers are finely ground into a powder and analyzed with an X-ray diffractometer using monochromatic Cu K α radiation at a wavelength of 1.5406 Å. The Percentage Crystallinity (% Cr), Crystallinity Index (CI), and Crystalline Size (CS) of the natural fibers are then calculated using specific equations.

$$\text{Crystallinity \%} = \frac{I_{200} - I_{\text{amp}}}{I_{200}} \times 100$$

$$\text{Crystallinity Index} = \frac{I_{200} - I_{\text{amp}}}{I_{200}}$$

where, I_{200} and I_{amp} are the crystalline and amorphous peaks at 2θ scale.

$$\text{Crystallinity Size} = \frac{K\lambda}{\beta \cos\theta}$$

where, $K = 0.9$, $\lambda = 1.54060 \times 10^{-10}$ m; $\beta = \frac{\pi}{180} \times \text{FWHM}$, θ -Bragg's angle.

X-ray diffraction analysis is used to study the diffraction angles (2θ) of crystalline and amorphous peaks in treated Luffa fiber [5]. Fig 2 shows the PXRD pattern of chemically

processed luffa fibre. Using the formula, the percentage crystallinity of treated Luffa fiber is found to be 65.45%.

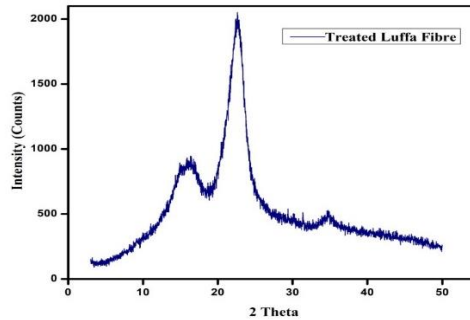


Fig. 2. PXRD Pattern of treated Luffa fibre

3.2. SEM Analysis

SEM images of treated fibers reveal irregular white spots on the surface. Sodium acetate treatment reduces hemicellulose and removes wax, creating a rougher fiber surface. This enhances bonding at the fiber-matrix interface, improving interfacial adhesion and the fiber's ability to connect. Thinner fibers are preferred in composites for added strength and stiffness. Fig 3 shows the scanning electron microscope images of luffa fibre for different magnifications.

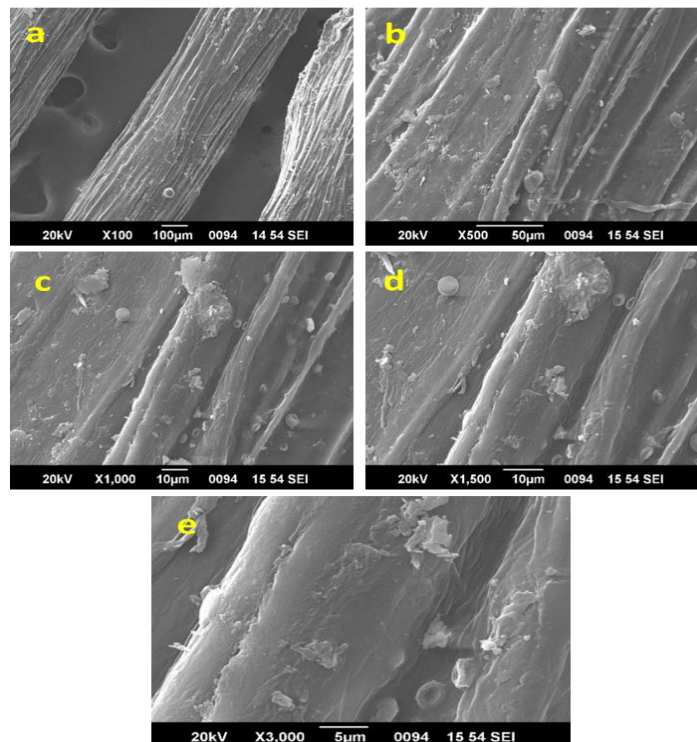


Fig. 3. SEM images of treated Luffa fibre with magnifications (a) $\times 100$ (b) $\times 500$ (c) $\times 1000$ (d) $\times 1500$ (e) $\times 3000$

3.3. EDAX Analysis

EDAX analysis measures the elemental composition on the surface of treated Luffa fiber. Table 1 shows the elements detected, with their atomic and weight percentages. The main peaks are for carbon and oxygen, and the table provides details on each element's atomic weight and percentage. Fig 4 shows the EDAX Spectrum of treated Luffa fibre.

Table 1. Weight % and Atomic % of various elements present in treated Luffa fibre

Element	Weight %	Atomic %
C	55.27	62.21
O	44.73	37.79
Total	100	100

The O/C ratio, determined through EDAX analysis, measures the oxygen-to-carbon ratio in natural fibers. A high carbon content indicates more lignin, while a high O/C ratio suggests lower lignin content. This ratio helps explain the different properties of natural fibers.

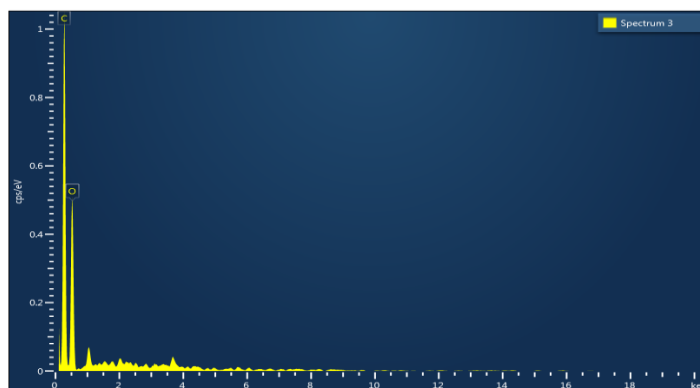


Fig. 4. EDAX Spectrum of treated Luffa fibre

3.4. Thermo-gravimetric (TGA) Analysis

Thermal analysis is a widely used method to study the decomposition of solid materials, with heat degradation occurring in two or three stages based on the fibers' chemical composition. A TG plot shows temperature (x-axis) against weight loss percentage (y-axis). Table 2 presents the mass loss for treated fibers, with degradation occurring below 340°C. The main mass loss (35-45%) happens above 290°C due to crystalline cellulose breakdown. Fig 5 (a) and (b) shows the TG and DTG curve of treated Luffa fibre.

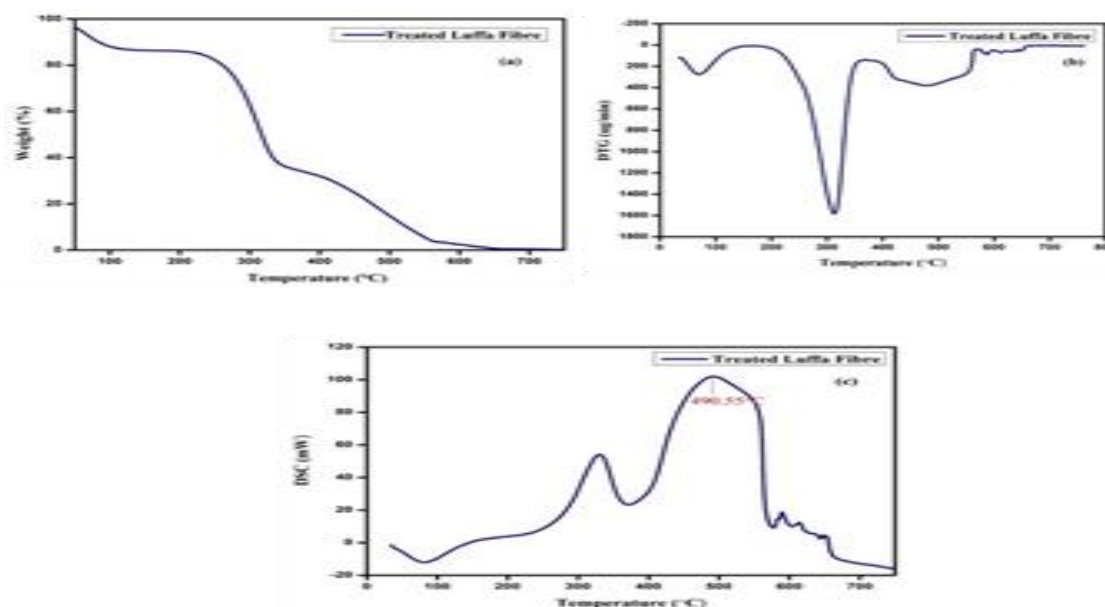
Table 2. Thermal study of sodium acetate treated Luffa fibre

Fibre Type	Temperature during mass loss (°C)	Mass Loss	Residual mass at 700°C (%)
Treated Luffa Fibre	0 - 140	13%	0.38%
	140 - 290	20%	
	290 - 340	40%	

The DTG curve identifies the peak of fiber deterioration, aligning with the peak values on the TG curve, confirming the fiber's thermal stability. Table 3 shows the mass loss at T_{max} for treated Luffa fibers, while Fig. 5 (c) presents DSC profiles. An exothermic peak at 490°C indicates the release of the lignified component in treated Luffa fiber.

Table 3. Mass loss at T_{max} of treated Luffa fibre

Sample	Total mass loss (%)			Max. Temperature Limit (°C)	T (50%) (°C)
	First stage	Second stage	Third stage		
Treated luffa fibre	13%	20%	40%	340	320

**Fig. 5. (a) TG Curve (b) DTG Curve and (c) DSC Curve of sodium acetate treated Luffa Fibre**

3.5. FTIR Analysis

Fourier Transform Infrared (FTIR) analysis identifies the functional groups in treated Luffa fiber, with IR spectra measured between 4000 and 400 cm^{-1} . Each material shows unique IR absorption frequencies based on the atomic masses in each bond. Key wave

numbers include 3424 cm^{-1} for O-H stretching (α -hemicellulose), 2921 cm^{-1} for C-H stretching (α -cellulose), and 1635 cm^{-1} for C-O carboxyl stretching (hemicellulose). Additional peaks, such as 1383 cm^{-1} and 1241 cm^{-1} , correspond to COC and C-O stretching in lignin and hemicellulose, shows in Fig 6.

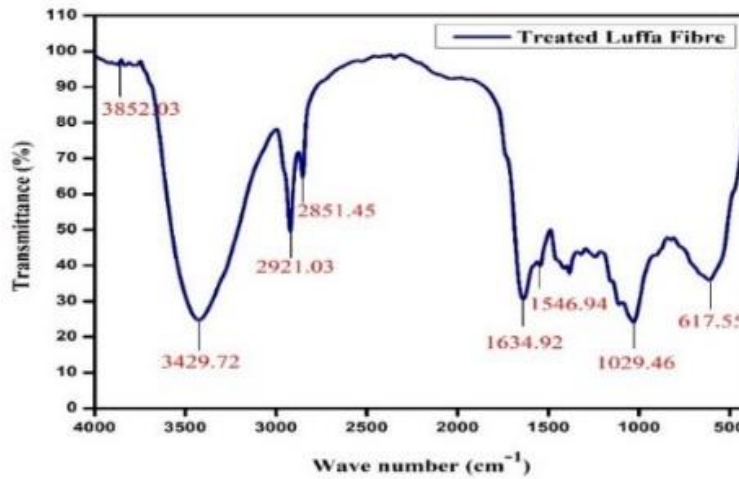


Fig. 6. FTIR Spectrum of sodium acetate treated Luffa Fibre

3.6. Physical analysis

3.6.1. Density

Low density is a key feature of natural fibers, distinguishing them from synthetic fibers as reinforcements in lightweight applications. Fiber density is crucial when assessing suitability for composite materials. Figure 7 shows a pycnometer, with toluene as the immersion liquid.



Fig. 7. Density of the fibre using Pycnometer

The density of the treated luffa fibre can be calculated by using the formula,

$$\text{Density of the fibre, } \rho = \frac{(m_2 - m_1)}{(m_3 - m_1) - (m_4 - m_2)} \rho_t$$

Where,

m_1 - mass of dry empty pycnometer (g)

m_2 - mass of pycnometer + fibre (g)

m_3 - mass of pycnometer + Toluene (g)

m_4 - mass of pycnometer + Toluene +fibre (g)

ρ_t - density of toluene (0.867g/cm³)

Table 4. Density Measurement using Pycnometer

Sample	Mass (g)				Density of Toluene ρ_t (g/cm ³)	Density of fibre ρ (g/cm ³)
	m_1 (g)	m_2 (g)	m_3 (g)	m_4 (g)		
Treated Luffa Fibre	13.77	15.192	22.733	23.226	0.867	1.346

Lower density values of 1.346 g/cc are recorded for the Luffa fibres. Lower density gives a wide scope for the fibres to be employed as reinforcement while making composites. Table 4 shows the density measurements using a pycnometer.

3.6.2. Diameter of the Fibre

The diameter of a natural fiber, measured through its center, impacts the fabric's performance and texture. For sodium acetate-treated *Luffa cylindrica* samples, the average fiber diameter is 0.0453 cm.

4. Conclusion

Modified Luffa fiber, analyzed using PXRD, SEM-EDAX, TGDTA, FTIR, and density methods, shows high crystallinity (65.45%), strong mechanical strength, and a rough surface, ideal for composite matrices. High carbon content enhances its thermal stability, while thermal and FTIR studies identify its functional properties. These qualities make treated Luffa fiber an eco-friendly reinforcement option for biocomposites in industries like furniture, automotive, and construction.

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Modified CuO-Mn₂O₃ and CuO-Fe₂O₃ Nanocomposites Synthesized Via Ultrasonication- Assisted Co-Precipitation for Sensor Applications

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ABSTRACT

Modified CuO-Mn₂O₃ and CuO-Fe₂O₃ nanocomposites were synthesized via ultrasonication-assisted co-precipitation method. The method combines the high reactivity of co-precipitation with sonication capability to produce homogeneously dispersed nanoparticles with enhanced surface properties. The structural characteristics of the nanocomposites were examined using X-ray diffraction (XRD), confirming the successful formation of CuO-Mn₂O₃ and CuO-Fe₂O₃ phases. UV-Vis spectroscopy and Photoluminescence (PL) analysis were used to investigate the optical properties of the synthesized nanocomposites, offering valuable information about their electronic structures and band gaps, which are essential for improving sensitivity in sensor applications.

Keywords: Nanocomposites, Oxide, PXRD, Absorption

1. Introduction

In recent years, nanoscale structures have garnered significant interest from the research community due to their remarkable physical, chemical, mechanical, and electrical properties. [1,2]. Nanocomposites are a fascinating application of nanoscience. They are materials composed of a matrix embedded with nanoparticles or nanostructures. The inclusion of these nanomaterials can greatly improve the properties of composite materials [3,4]. Copper oxide (CuO) nanostructures are particularly intriguing due to their unique properties and potential applications in batteries, supercapacitors, solar cells, gas sensors, biosensors, nanofluids, catalysis, photodetectors, energetic materials, field emission, superhydrophobic surfaces, and the removal of arsenic and organic pollutants from wastewater. When combined with Mn₂O₃ and Fe₂O₃, CuO-based nanocomposites can further enhance these properties [5-6].

2. Materials and Methods

In this project work, high quality CuO-Mn₂O₃ and CuO-Fe₂O₃ nanocomposites are synthesized by ultrasonication assisted co-precipitation method. Cupric sulphate (7.490 g)

was dissolved in 100 ml of distilled water and stirred for 60 minutes using a magnetic stirrer. Separately, manganese acetate (7.3527 g) was dissolved in 100 ml of distilled water and stirred thoroughly. Both the cupric sulphate and manganese acetate solutions were then combined. Next, Sodium hydroxide was dissolved in 100 ml of distilled water and stirred well. The sodium hydroxide solution was added drop by drop to the mixed solution while maintaining a pH of 10. The resulting precipitate was placed in an ultrasonicator (Powersonic 405S) and washed five times with double-distilled water, followed by two washes with ethanol and double-distilled water. The precipitate was then dried in a hot air oven at 100°C. The resulting sample was brown in color. After grinding, the sample was heated in a muffle furnace at 400°C for two hours, yielding a black CuO-Mn₂O₃ nanopowder. A similar procedure was followed for the synthesis of CuO-Fe₂O₃ nanocomposites, using cupric sulphate and ferric chloride as precursors.

3. Results and Discussion

PXRD analysis

The structural characterization of the CuO-Mn₂O₃ and CuO-Fe₂O₃ nanocomposites were analyzed by recording the powder X-ray diffraction (PXRD) spectra using an X-ray diffractometer. The crystal grain size can be quantitatively estimated using the Scherrer equation and the diffraction peak broadening in the XRD curves.

$$D = \frac{0.9\lambda}{\beta \cos\theta}$$

Where λ is the wavelength of the Cu- K α radiation [1.54060 Å], β is the full width half maximum of the diffraction line and θ is the angle of diffraction. Figure 1 displays the PXRD pattern of the synthesized CuO-Mn₂O₃ nanocomposites, with peaks observed at (222), (431), (521), and (026) corresponding to 2θ values of 32.95°, 49.35°, 53.29°, and 62.37°, respectively. The CuO peaks are observed at (002), (111), (022), and (004), corresponding to 2θ values of 35.39°, 38.29°, 64.98°, and 75.01°, respectively. The Mn₂O₃ peak, corresponding to (002), exhibits a high relative intensity. The average grain size, D , is 21.39 nm. The 2θ values obtained from the PXRD data for Mn₂O₃ in the CuO-Mn₂O₃ nanocomposites closely match those of the JCPDS File No. 65-1798, and its structure is determined to be cubic. The CuO structure in the synthesized CuO-Mn₂O₃ nanocomposites is monoclinic. Figure 2 shows the PXRD pattern of the CuO-Fe₂O₃ nanocomposites. The peaks for Fe₂O₃ are observed at (011), (013), (201), (211), (114), (214), and (330) with 2θ values of 13.75°, 30.15°, 36.504°, 37.95°, 43.50°, 53.94°, and 63.23°, respectively. The CuO peaks are observed at (004) and (202), corresponding to 2θ values of 58.16° and 75.01°. The CuO peak at (201) exhibits the highest relative intensity. The 2θ values for iron oxide in the

CuO-Fe₂O₃ nanocomposites match well with the JCPDS File No. 89-7047, and the structure is determined to be orthorhombic. The structure of CuO was monoclinic in the synthesized CuO-Fe₂O₃ nanocomposites. The average grain size D is 20.554389 nm [7].

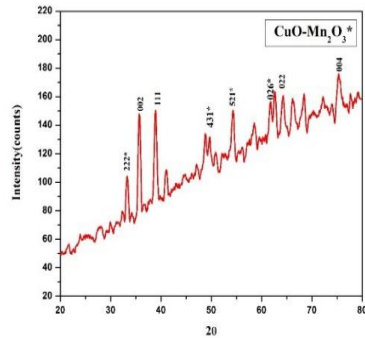


Fig. 1. PXRD pattern of CuO – Mn₂O₃ Nanocomposites

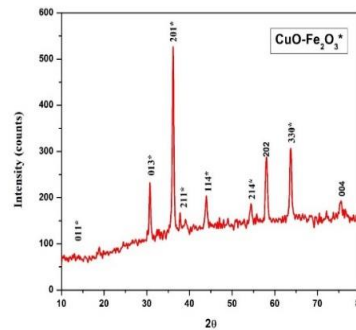


Fig. 2. PXRD pattern of CuO-Fe₂O₃ Nanocomposites

Photoluminescence (PL) analysis

Photoluminescence (PL) studies for the synthesized CuO- Mn₂O₃ and CuO- Fe₂O₃ nanocomposites were carried out using a photoluminescence spectrophotometer and the emission spectra were recorded at a scan rate of 600 nm/min using the excitation wavelength of 320 nm. The PL emission spectra of CuO-Mn₂O₃ and CuO- Fe₂O₃ nanocomposites exhibit a prominent peak at 358 nm, which corresponds to blue emission, likely due to the radiative recombination of charge carriers or defect states involving Mn²⁺ or Mn³⁺ ions. The smaller peaks at 388 nm and 406 nm are attributed to blue-green emissions, which are associated with defect states or surface defects, possibly linked to oxygen vacancies in the material. The peak at 489 nm corresponds to green emission, likely arising from electron-hole recombination or shallow defects, while the 570 nm peak is a yellow emission, which is typically related to deep-level trap states or significant defects, such as oxygen vacancies. For the CuO-Fe₂O₃ nanocomposites, the primary peak at 358 nm also corresponds to blue emission, and the smaller peaks at 387 nm and 406 nm indicate blue-green emissions due to similar defect-related phenomena involving oxygen vacancies or point defects in the CuO-Fe₂O₃ matrix [8].

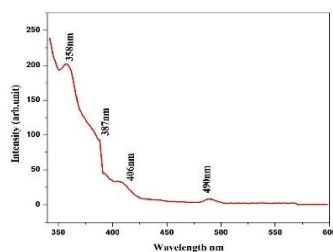


Fig. 3. PL spectra of CuO- Mn₂O₃ Nanocomposites

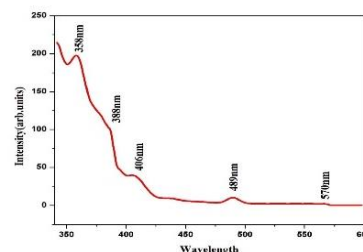


Fig. 4. PL emission spectra of CuO-Fe₂O₃ Nanocomposites

UV– Visible analysis

Figure 5 displays the optical absorbance spectra of CuO-Fe₂O₃ nanocomposites, showing a maximum peak at 352 nm with significantly absorbance. Similarly, Figure 6 presents the optical absorbance spectra of CuO-Fe₂O₃ nanocomposites, also exhibiting a peak at 352 nm. The UV peaks observed in the blue region for both CuO-Mn₂O₃ and CuO-Fe₂O₃ nanocomposites confirm the nanoscale nature of the synthesized materials [9].

The optical band gap is calculated by using the relation

$$\alpha h\nu = A (h\nu - E_g)^n$$

where, A is a characteristic parameter independent of photon energy, h is Planck's constant, ν is the frequency of light, E_g is the optical energy band gap, and n defines the type of electronic transition. For direct allowed transitions, $n = 2$ and for indirect allowed transitions $n=1/2$. The Tauc plot method is commonly used to determine (E_g) by plotting $(\alpha h\nu)^2$ against $h\nu$ (photon energy). The optical band gap is estimated by identifying the linear region of the plot and extrapolating it to intersect the energy axis (x-axis) at zero. Using this method, the optical band gap was determined to be $E_g=4.2$ eV for CuO-Mn₂O₃ nanocomposites (Fig. 7) and $E_g=3.7$ eV for CuO-Fe₂O₃ nanocomposites (Fig. 8). These differences in bandgap values highlight the distinct electronic properties of the nanocomposites, crucial for optimizing their optoelectronic performance in specific applications.

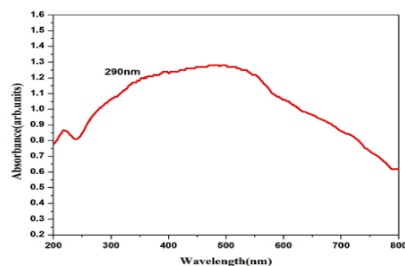


Fig. 5. Optical absorbance spectra of Mn₂O₃ nanocomposites

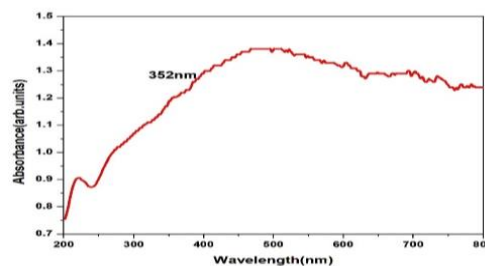


Fig. 6. Optical absorbance spectra of CuO-Fe₂O₃ nanocomposites

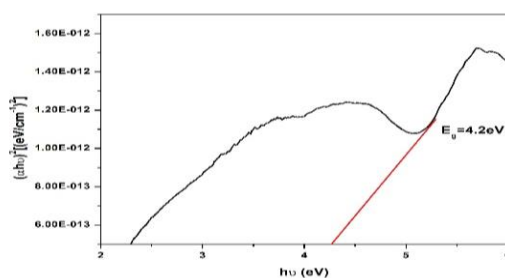


Fig. 7. Optical Energy band gap of CuO-Mn₂O₃ CuO- Nanocomposites

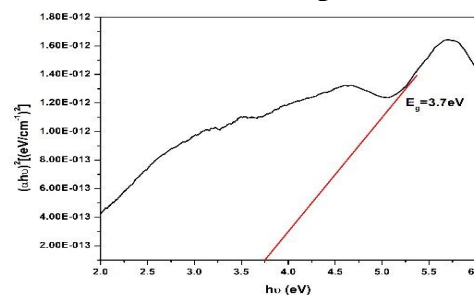


Fig. 8. Optical Energy band gap of Fe₂O₃ nanocomposites

4. Conclusion

The CuO-Mn₂O₃ and CuO-Fe₂O₃ nanocomposites synthesized by ultrasonication-assisted co-precipitation have demonstrated excellent optical and electronic properties for heavy metal sensing. UV-Vis spectroscopy confirmed strong light absorption in the visible range, while photoluminescence studies provided valuable insights into charge carrier dynamics, essential for achieving high sensor sensitivity and selectivity. The enhanced optical properties, combined with high surface area and effective electron transfer, contribute to the nanocomposites' remarkable sensitivity and low detection limits for Pb²⁺, Cd²⁺, and Hg²⁺ ions. These findings highlight the potential of CuO-Mn₂O₃ and CuO-Fe₂O₃ nanocomposites as efficient, cost-effective sensors for monitoring toxic metal ions in environmental applications.

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Hydrothermally synthesized pure ZnO and ZnO-MgO nanostructures for Solar Cell Applications

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ABSTRACT

Hydrothermal synthesis offers an efficient and eco-friendly route to fabricate nanostructures with enhanced properties for solar cell applications. In this study, pure zinc oxide (ZnO) and zinc oxide-magnesium oxide (ZnO-MgO) nanostructures were synthesized by hydrothermal method and characterized to explore their potential as photoanode materials in solar cells. The structural analysis using PXRD revealed high crystallinity and phase purity, while photoluminescence (PL) analysis highlighted reduced recombination rates due to MgO doping. Optical characterization using UV-Vis spectroscopy showed improved light absorption for ZnO-MgO nanostructures with a widened bandgap. These enhancements are critical for improving the efficiency of solar cells. The results demonstrate the promise of hydrothermally synthesized ZnO-MgO nanostructures for next-generation photovoltaic applications.

Keywords: nanocomposites, metal oxide, PXRD, photocatalytic

1. Introduction

Nanocomposites comprise various systems, for instance, multidimensional (1D, 2D, 3D) and amorphous materials, which are made of several different components with varied characteristics, with the dimension less than 100 nm. The incorporation of these materials serves to enhance the properties of the nanomaterials to function more effectively for the intended applications [1-3]. ZnO has a wide band gap (~ 3.37 eV), which makes it transparent to visible light, allowing more light to pass through to the active layers of solar cells. Its high electron mobility promotes efficient charge transport, reducing energy loss and enhancing solar cell efficiency. [4-6]. To further enhance its effectiveness, ZnO is often combined with other materials to form nanocomposites. Among these, magnesium oxide MgO emerges as a promising candidate due to its renowned stability and bandgap engineering properties. The hydrothermal synthesis method, recognized for its ability to produce high purity, defect-free nanostructure, offers a controlled and efficient method for fabricating ZnO-MgO nanocomposites. The formation of ZnO-MgO nanocomposites through hydrothermal

synthesis produces stable, defect-free, and uniform structures that are well-suited for absorbing sunlight and sustaining efficient photovoltaic performance [7-9]. This technique enables the creation of nanomaterials with enhanced functional characteristics, making them suitable for advanced solar cell application.

2. Materials and Methods

In this project work, high-quality pure ZnO and ZnO-MgO nanostructures are synthesized by the hydrothermal method. The materials used for preparing the nanomaterials consist of zinc acetate, manganese acetate, magnesium acetate, double distilled water and hydroxide. 0.1 M of zinc acetate dihydrate and 0.1 M of MgCl₂ are separately dissolved in 100 ml of distilled water and then it is mixed together and the solution is under vigorous stirring for 10 minutes. Then, 3M of NaOH, dissolved in 100 ml of distilled water is slowly added to the solution in order to maintain the pH value 10 which results in the formation of white precipitate. Then the solution is stirred for 5 minutes and transferred into the autoclave and closed at 160 °C for 12 hrs and cooled at room temperature. The resultant colourless products are cleaned and rinsed with distilled water and ethanol for 3 times and placed in the hot air oven for drying and then, it is kept in the muffle furnace for 500° C and finally, the ZnO-MgO nanopowder obtained appears white in colour. ZnO nanopowder is also synthesized using the same method as mentioned above.

3. Results and Discussion

3.1 PXRD analysis

The structural properties of the pure ZnO nanoparticles and ZnO-MgO nanocomposites are analyzed by recording the powder X-ray diffraction (PXRD) spectra using X-ray diffractometer. The average grain size can be quantitatively estimated using the Scherrer equation and the diffraction peak broadening in the XRD curves.

$$D = \frac{0.9\lambda}{\beta \cos\theta}$$

where λ is the wavelength of the Cu-K α radiation [1.54060 Å], β is the full width half maximum of the diffraction line and θ is the angle of diffraction. Fig.1 depicts the PXRD pattern of the synthesized Pure ZnO nanoparticles. The peaks of ZnO are observed at (100), (002), (101), (102), (110), (103), (112) and (201) corresponding to $2\theta = 31.6834^\circ$, $2\theta = 34.3185^\circ$ and $2\theta = 36.2542^\circ$, $2\theta = 47.5045^\circ$, $2\theta = 56.5110^\circ$, $2\theta = 62.8222^\circ$, $2\theta = 67.8745^\circ$, $2\theta = 69.0411^\circ$, $2\theta = 72.4610^\circ$ and $2\theta = 76.9071^\circ$ respectively. The average grain size D is 30.20 nm using Scherrer equation. Fig.4.2 shows the PXRD pattern of the synthesized zinc oxide (ZnO) – magnesium (MgO) nanocomposites. The peaks of ZnO are observed at (100), (002),

(102), (110), (200), (112), (201), and (202) corresponding to $2\theta = 31.6617^\circ$, $2\theta = 34.3215^\circ$, $2\theta = 47.4385^\circ$, $2\theta = 56.4840^\circ$, $2\theta = 66.2877^\circ$, $2\theta = 67.8421^\circ$, $2\theta = 68.9600^\circ$ and $2\theta = 76.9280^\circ$ respectively and the peaks of MgO are observed at (111), (200) and (220) corresponding to $2\theta = 36.1469^\circ$, $2\theta = 42.6428^\circ$ and $2\theta = 62.7546^\circ$ respectively. The MgO peak corresponding to (111) is of high relative intensity. The average grain size D is calculated as 44.22 nm using Scherrer equation [10].

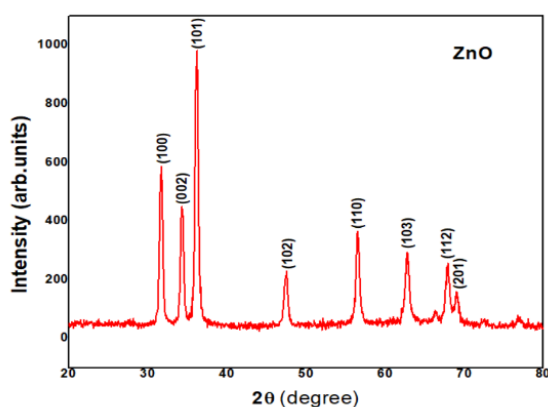


Fig. 1. PXRD pattern of pure ZnO nanoparticles

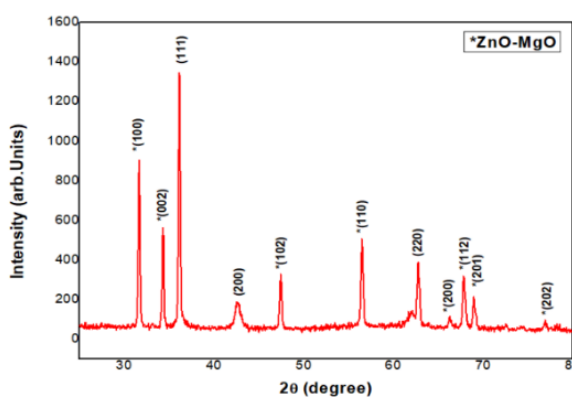


Fig. 2. PXRD pattern of ZnO-MgO nanocomposites

3.2 Photoluminescence (PL) analysis

Photoluminescence (PL) studies of the synthesized pure ZnO and ZnO-MgO nanocomposites were conducted using a photoluminescence spectrophotometer. The emission spectra were recorded at a scan rate of 600 nm/minutes employing an excitation wavelength of 320 nm. The PL emission spectrum of pure ZnO nanoparticles, presented in Fig. 3 exhibits prominent peaks at 358 nm, 392 nm, 408 nm, 436 nm, 490 nm, 521 nm, and 594 nm, each corresponding to distinct energy levels. In comparison, the PL emission spectrum of ZnO-MgO nanocomposites, shown in Fig. 4 reveals peaks at 359 nm, 390 nm, 406 nm, 491 nm, 519 nm, 540 nm, 571 nm, and 596 nm, each associated with specific energy levels. The PL emission peaks in the blue and green regions for both ZnO and ZnO-MgO nanocomposites indicate the nanoscale nature of the synthesized materials [10].

3.3 UV– Visible analysis

The absorbance of the synthesized pure ZnO nanoparticles is shown in Fig.5 which exhibits a maximum peak at 357 nm with absorbance 1.2 (a.u.). The absorbance of the synthesized ZnO-MgO nanocomposites is shown in Fig.6 which exhibits a maximum peak at 363 nm with absorbance 0.75 (a.u.) [11]. The optical band gap is calculated by using the relation

$$\alpha h\nu = A (h\nu - E_g)^n$$

where, A is a characteristic parameter independent of photon energy, h is Planck's constant,

ν is the frequency of light, E_g is the optical energy band gap, and n defines the type of electronic transition. For direct allowed transition, $n = 2$ and for indirect allowed transition $n = 1/2$. The

Tauc plot method is a commonly used to determine (E_g) by plotting $(\alpha h\nu)^2$ against $h\nu$ (photon energy). The optical band gap is estimated by identifying the linear region of the plot and extrapolating it to intersect the energy axis (X-axis) at zero. Using this method, the optical band gap was determined to be $E_g = 3.06\text{eV}$ for ZnO nanoparticles and ZnO-MgO nanocomposites (Fig. 7 & 8). These differences in bandgap values highlight the distinct electronic properties of the nanoparticles and nanocomposite, crucial for optimizing their optoelectronic performance in specific application.

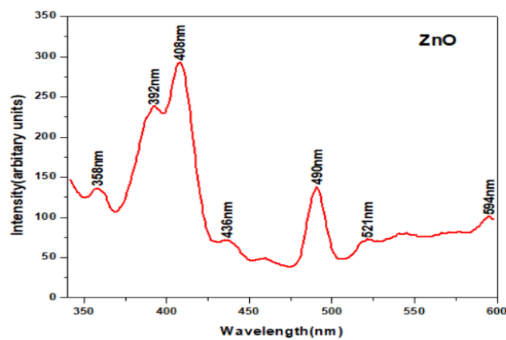


Fig. 3. PL emission spectra of ZnO nanoparticles

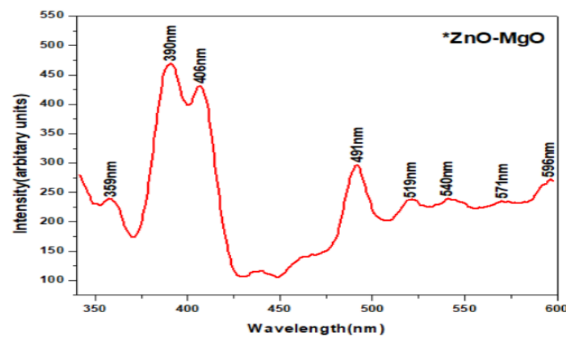


Fig. 4. PL emission spectra of ZnO-MgO nanocomposites

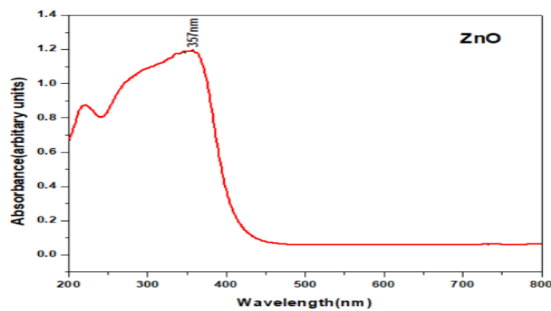


Fig. 5. Optical absorbance spectra of ZnO- nanoparticles

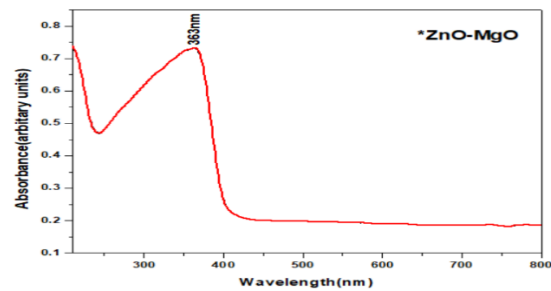


Fig. 6. Optical absorbance spectra of ZnO-MgO nanocomposites

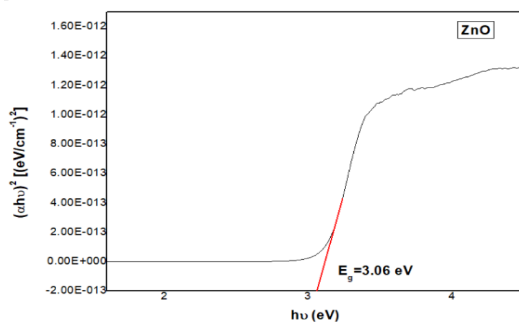


Fig. 7. Optical Energy band gap of ZnO nanoparticles

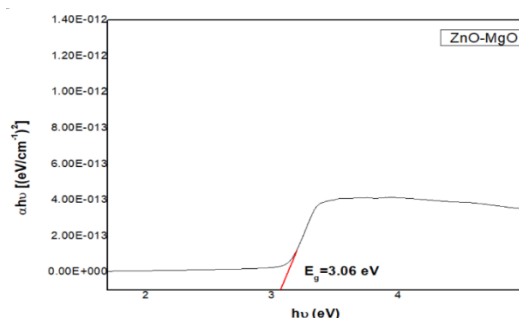


Fig. 8. Optical Energy band gap of ZnO-MgO nanocomposites

3. Conclusion

The study successfully synthesized and characterized pure ZnO nanoparticles and ZnO-MgO nanocomposites using the hydrothermal method. PXRD confirmed well-defined crystalline structures with average grain sizes of 30.20 nm for ZnO and 44.22 nm for ZnO-MgO. The addition of MgO enhanced absorption and shifted diffraction peaks, indicating successful composite formation. PL and UV-Vis studies revealed emission peaks in the blue and green regions and a band gap of 3.06 eV for both materials, highlighting their nanoscale nature and improved optical properties. These findings demonstrate the potential of ZnO-MgO nanocomposites for applications in solar cells and other photoactive devices.

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Growth and Characterization of Pure and Lithium Nitrate Doped Gsn Single Crystals

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ABSTRACT

The work is a thorough study of pure and lithium nitrate doped GSN single crystals. These crystals were meticulously grown through the slow evaporation method, and a series of precise characterization techniques were meticulously applied to unravel their intrinsic qualities. To unveil the structural composition of the crystals, a Powder X-ray Diffraction analysis was meticulously conducted. Moreover, the identification of specific functional groups was facilitated through detailed Fourier Transform Infrared Spectral (FTIR) studies. Additionally, an exploration of the crystals' optical properties was carried out through comprehensive UV-Vis spectral studies, aided in revealing a lower cut off wavelength of 230 nm, shedding light on their NLO efficiency and behavior under various wavelengths of light.

Keywords: GSN, semi organic crystals, Nonlinear optics, Slow evaporation

1. Introduction

Crystals have piqued man's curiosity for centuries due to their beauty and scarcity. Crystals were employed for both development and ornamentation during the middle Ages. However, with the introduction of crystallography, all solids with distinct geometrical shapes were classified as crystalline solids. There are three major categories of solids: Crystalline, amorphous, and quasicrystalline [1]. A crystalline state is defined by the orderly arrangement of component molecules or ions into a definite pattern known as a lattice. The arrangement is irregular when the material is amorphous. When crystals form slowly, the atoms or component particles occupy certain locations during the process. These component particles settle down in places where their potential energy is lowest. As a result, an ordered arrangement of component particles emerges, repeating itself in all three directions. When there is long-range organisation in a solid, it is known as a crystalline solid. If the development process is rapid, these component particles do not reach the configuration of minimal energy. This produces long-range order, in which perfect periodicity is maintained at

far greater distances than lattice periodicity. However, there is still a short-range order in which order exists in small locations.

Amorphous solids are defined by their short-range organisation. Quasicrystals, a third type of solids, are crystals that contain atoms in ordered arrays but whose patterns shift somewhat at regular intervals. Such patterns are referred to as quasi periodic. When heated, some organic crystals change into a state somewhere between solid and liquid [2]. This condition is known as the mesomorphic state or liquid crystal. Crystals can range in size from a fraction of a millimetre to tens of centimetres or even meters. There are three types of crystals: macro, micro, and nano. Macro crystals are visible (bulk single crystals) and range in size from a few millimetres to 10⁻³ meters. Micro crystals are crystals that are extremely tiny. Nano crystals are crystals with size of 10⁻⁷ m or larger. The variation in crystal forms and sizes is controlled by two factors: the crystal's internal symmetry and the relative growth rate, which changes with the direction of crystal growth [3]. Single crystals have symmetrical periodicity throughout the material, and there are no inner borders. Twinned crystals are formed when two crystals are joined together, whereas multiplex crystals are formed when two or more crystals are attached together. They are often described as being polycrystalline in nature. Crystals have acute melting points, are stiff, and incompressible. Many of the key physical characteristics of crystals are due to their perfect ordering, including ferromagnetism, ferroelectricity, piezoelectricity, and birefringence [4].

Slow evaporation has emerged as a highly effective technique for crystal growth, having facilitated the successful growth of a wide array of compounds utilizing this method. By employing slow evaporation, a single solvent or a combination of two solvents is dissolved, and the resulting solution is left to evaporate gradually. This process can be carried out either under normal atmospheric conditions or within an inert atmosphere. The gradual evaporation method in crystal growth has proven to be particularly advantageous due to its ability to yield high-quality crystals with a high degree of purity. Not only does this technique promote crystal growth efficiency, but it also allows for a controlled and precise formation process, resulting in crystals exhibiting superior structural integrity. Additionally, the slow evaporation process offers researchers a versatile approach to growing crystals with varying properties and characteristics. This method has significantly broadened the scope of crystal growth possibilities, enabling the synthesis of crystals that may have been challenging to produce using other methods. Therefore, slow evaporation stands as a fundamental technique in the realm of crystal growth, offering researchers a reliable and versatile approach to achieving crystalline structures of varying complexities and compositions.

2. Materials and Methods

Growth of pure GSN

Single crystals of glycine sodium nitrate (GSN), a semi-organic nonlinear optical material, have been produced from solution via slow evaporation at room temperature. GSN's solubility has been determined in water. The amount of solute required to get supersaturated solution can be obtained using the formula [9],

$$M = [M \times X \times V] \div 1000$$

Where, M-Molecular weight of the solute, X-Supersaturated concentration in molar unit, V-Volume of the solution. The aqueous solution was evaporated under slow evaporation at room temperature.

Growth of 1 mole of Lithium Nitrate doped GSN

Single crystals of pure and lithium nitrate doped glycine sodium nitrate were grown from aqueous solution by slow evaporation technique. Glycine and sodium nitrate of high purity were dissolved in water in the ratio 1:1 to get a saturated solution. A Magnetic stirrer was used to obtain a homogeneous solution. The solution was then filtered and covered with a porous cover and kept undisturbed in a dust free environment. The amount of dopant required in grams is obtained using the formula,

$$M' = [M \times V \times P \times X] \div 100$$

where, M'-Molecular Weight of the dopant, V-Volume of the solution, X- Supersaturated concentration in molar unit. The solution is transferred to a beaker and kept in a dust free atmosphere to facilitate growth by slow evaporation at room temperature. A colorless crystal of GSN doped with 1 mole of lithium nitrate is produced using the slow evaporation approach.

Characterizations

X-Ray Diffraction studies

Power XRD patterns of the grown crystals were recorded using an automated X-ray power diffractometer (PANalytical XPERT-PRO MPD). This is a fully computerized X-ray diffractometer which was employed for X-ray diffraction studies. This is a versatile, sensitive and high-resolution X-ray diffractometer. The intensity of the diffracted beam was recorded against 2θ in the range 10 to 70° with $\text{CuK}\alpha$ radiation. Using the observed 2θ (Bragg angle) and d (interplanar spacing), all the reflection of the powder XRD pattern for pure and impurity added GSN crystal has been indexed.

UV-Vis spectral measurements

In the present study, the UV – Vis – NIR transmission spectra were recorded for the pure and impurity doped Lithium nitrate single crystals of 2 mm thickness. Perkin – Elmer Lambda 35 UV – Visible spectrometer in the range 190 – 1100.

Fourier Transform Infrared analysis

The FTIR spectra of pure and semi organic GSN crystals doped with impurity (0.2,0.4,0.6,0.8 and mole%), have been recorded in the in the range of 400-4000 cm^{-1} using Perkin Elmer Fourier transform infrared spectrometer (Model: Spectrum RXI) using KBr pellet method. The spectra were used to analyse the presence of different constituents and their bonding properties qualitatively.

3. Results and Discussion

XRD analysis

The diffraction pattern for the pure and doped GSN crystals was analysed using X' Pert Pro – P Analytic in the 2θ range from 10° – 70° with Copper ($K\alpha$) radiation ($\lambda = 1.5406 \text{ \AA}$) operating at a voltage of 40 kV and a current of 30 mA. The obtained XRD patterns are shown in the fig 1a,1b. The lattice parameters reveal the crystal belongs to the monoclinic system. The cell parameters $a = 14.41904 \text{ \AA}$, $b = 5.00504 \text{ \AA}$, $c = 9.27421 \text{ \AA}$, $\beta = 119.1078$ and cell volume $V = 584.7714 \text{ \AA}^3$, respectively were found using UNIT CELL software. The cell parameters for LiNO_3 doped GSN was found to be $a = 14.72713 \text{ \AA}$, $b = 5.38668 \text{ \AA}$, $c = 9.08003 \text{ \AA}$, $\beta = 118.58167$ and cell volume $V = 632.5410 \text{ \AA}^3$ respectively. The XRD pattern of the doped GSN crystal shows slight variations from the pure form of GSN crystals revealing the inclusion of the dopant into the lattice system [10], also the sharp peaks found in the diffraction pattern indicates the crystalline nature of the material [11].

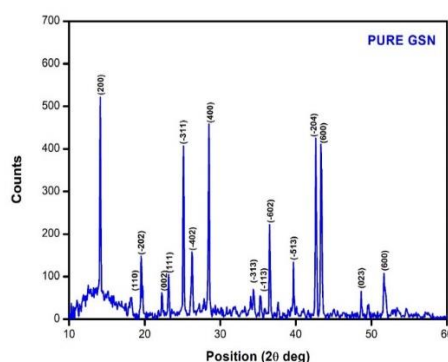


Fig. 2: XRD pattern of pure GSN

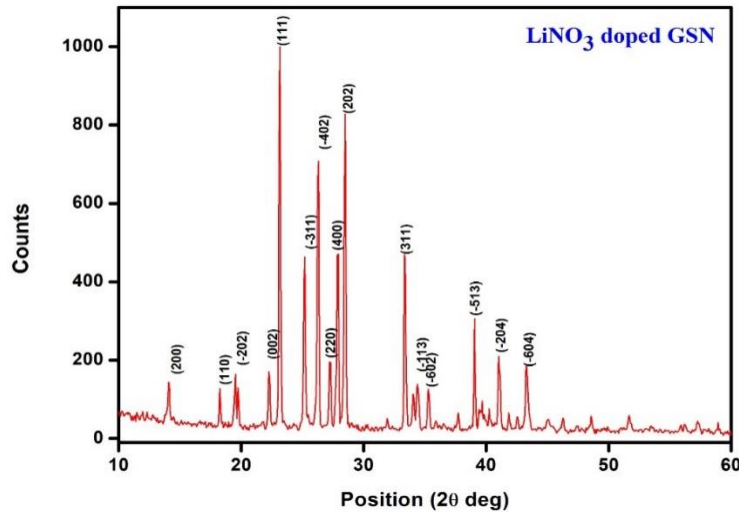


Fig. 3: XRD pattern of LiNO_3 doped GSN

UV- Vis Spectral Analysis

In the present work, UV-Vis-NIR spectra were recorded in the wavelength range of 190 nm – 1100 nm for the solutions of pure and Lithium nitrate doped GSN crystals using U-2900 spectrophotometer.

The ratio of absorbance and transmittance is particularly significant in the case of Nonlinear optical crystal applications as higher transmission efficiency of NLO crystals are a necessity [12]. The UV-Vis spectra for both the pure and doped crystals of GSN indicate greater transmittance percentage [13] and lower cut off wavelength of 230 nm, hence indicating greater NLO capability. The transmittance spectra for pure and doped GSN are shown in Figures 4 and 5. The absorbance spectra of pure GSN and lithium doped GSN are shown in figures 6 and 7, respectively.

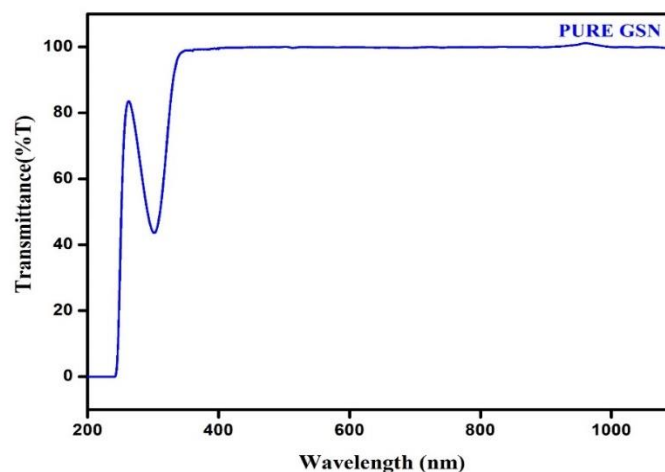


Fig. 4: UV – Vis transmittance spectrum of pure GSN

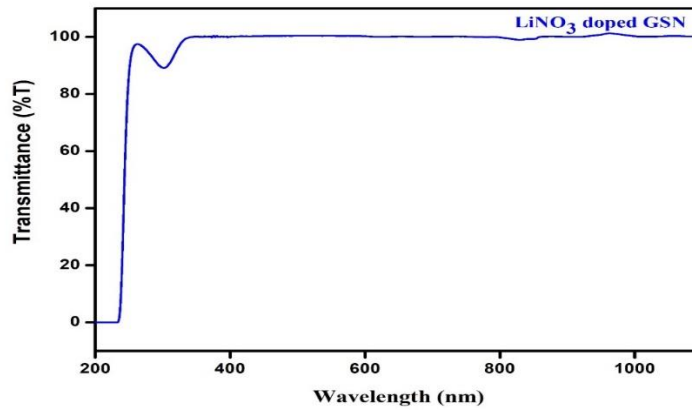


Fig. 5: UV – Vis transmittance spectrum of LiNO₃ doped GSN

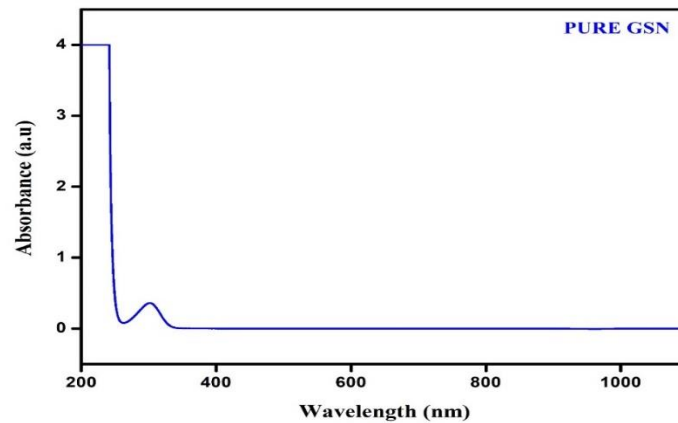


Fig. 6: Absorbance spectrum of pure GSN

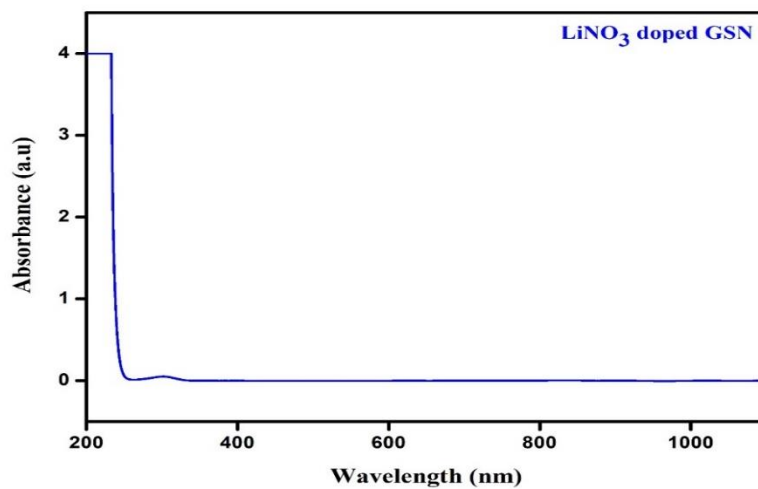


Fig. 7: Absorption spectrum of LiNO₃ doped GSN

FTIR Analysis

The peaks at 3257 cm^{-1} and 3260 cm^{-1} correspond to NH_3^+ Asymmetric stretching. CH_2 Asymmetric stretching is observed at the peaks at 2885 cm^{-1} and 2875 cm^{-1} respectively.

NH_3^+ symmetric stretching and NH_3^+ symmetric in plane bending is evident from the peaks at 2403 cm^{-1} and 1505 cm^{-1} . The presence of NO_3^- out of plane bending and NO_3^- in plane bending can be observed by peaks at 819 cm^{-1} and 673 cm^{-1} . Peaks at 1593 cm^{-1} and 505 cm^{-1} indicate the presence of COO^- asymmetric bending and COO^- rocking. The presence of C-N stretching is evident from peaks at 1023 cm^{-1} and 1028 cm^{-1} . Peaks at 2016 and 2019 represent a combination of torsional oscillation and asymmetric bending of NH_3^+ . The presence of NH_3^+ Rocking and CH_2 Rocking is proven by the peaks at 1126 cm^{-1} and 913 cm^{-1} [14].

The slight variations in the FTIR peaks of LiNO_3 doped GSN, indicates the inclusion of the dopant into the Glycine lattice [15]. The peak allotment of pure and doped samples of Glycine is given in Table 1. The corresponding FTIR graphs are provided in fig 8 and 9 respectively.

Table 1: FTIR spectral analysis of pure and doped Glycine

Wavenumber (cm^{-1})		Band assignment
Pure GSN	LiNO_3 doped GSN	
3257	3260	NH_3^+ Asymmetric stretching
2885	2875	CH_2 Asymmetric stretching
2717	2711	Overtone/combinations
2629	2618	Overtone/combinations
2403	2411	NH_3^+ symmetric stretching
2016	2019	Combination of torsional oscillation and asymmetric bending of NH_3^+
1593	1598	COO^- asymmetric bending
1505	1505	NH_3^+ symmetric in plane bending
1381	1377	NO_3^- asymmetric stretching
1126	1120	NH_3^+ Rocking
1023	1028	C-N stretching
913	907	CH_2 Rocking
819	828	NO_3^- out of plane bending
673	678	NO_3^- in plane bending
505	507	COO^- rocking, ONa^+ stretching

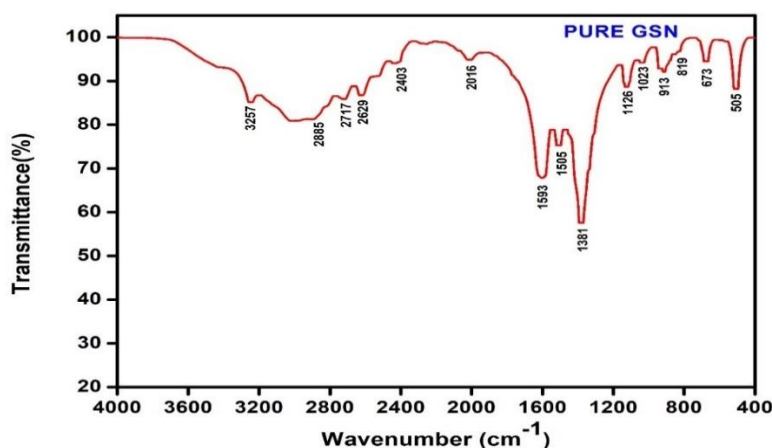


Fig. 8: FTIR spectra of pure GSN

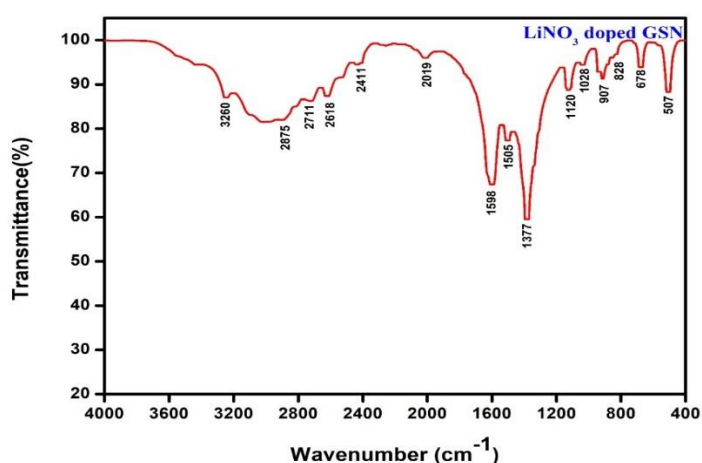


Fig. 9: FTIR spectra of LiNO₃ doped GSN

4. Conclusion

Single crystals of LiNO₃ doped Glycine Sodium Nitrate crystals were grown employing slow evaporation technique. The XRD patterns of the doped GSN crystal differ somewhat from the pure form of GSN crystals, indicating the presence of the dopant into the lattice system. The sharp peaks found in the diffraction pattern indicates the crystalline nature of the material. The functional groups of grown crystals were confirmed by FTIR studies. The UV-Vis spectra of GSN pure and doped crystals show a higher transmittance percentage and a lower cut off wavelength of 230 nm, this indicates greater NLO efficiency of these crystals.

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Eco-friendly Synthesis of Zinc Oxide Nanoparticles Using *Moringa oleifera* Leaf Extract

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ABSTRACT

This work investigates the environmentally friendly generation of Zinc oxide nanoparticles (ZnO NPs) by employing plant extract from Moringa oleifera [MO] as a stabilizing and reducing agent. The synthesized NPs were characterized using various techniques, including XRD, FT-IR, and UV-Vis. The XRD study confirms the hexagonal wurtzite-structured ZnO nanoparticles. This study highlights the use of MO extract in environmentally friendly manufacturing of ZnO nanoparticles, contributing to the development of nanomaterials.

Keywords: Coprecipitation method, green synthesis, Moringa oleifera, Sodium hydroxide, Zinc Oxide (ZnO).

1. Introduction

Metal oxide nanoparticles, particularly ZnO NPs, have garnered significant attention [1]. Traditionally, the manufacture of these NPs employs chemical methods, which often involve harmful reagents and energy-intensive processes. In response to the need for sustainable practices, researchers have been developing green synthesis methods, which utilize natural substances to produce nanoparticles without compromising the environment [2,3]. Using natural extracts eliminates toxic chemicals, reduces production costs, and provides an effective route to creating nanoparticles with enhanced biological activity [2,4]. The appeal of plant-mediated synthesis lies in its simplicity and compatibility with numerous applications. *Moringa oleifera* (MO), commonly called the drumstick tree or miracle tree is a fast-growing tree found predominantly in tropical regions [5]. These compounds are linked to a range of health benefits, including anti-inflammatory, antioxidant, anticancer, and immunomodulatory effects, making MO an excellent candidate for green synthesis [6]. In the manufacture of NPs, the bioactive chemicals in MO work as natural reducing agents, streamlining the manufacturing process. These phytochemicals not only facilitate the ZnO

NPs formation but also enhance their functional properties. In biomedicine, they exhibit potential in cancer therapy, and wound healing [5,7]. The adaptability of ZnO NPs makes them a crucial focus for researchers seeking to improve their synthesis and functionality through green methods. When used in green synthesis, MO contributes additional biological activity to the resulting ZnO NPs, making them more effective in various biomedical and environmental applications [8]. Using MO leaf extract for environmentally friendly ZnO NP generation provides multiple advantages. It gets rid of the use of hazardous chemicals, supports low-cost production, and enhances the nanoparticle's biological activity [3]. However, ongoing research is focused on optimizing green synthesis parameters to improve reproducibility and efficiency [9]. Future research may explore hybrid methods and combinations with other biocompatible materials to enhance the functional properties of *Moringa oleifera* ZnO NPs (MO-ZnO NPs) [10,11]. The outcome of this research contributes to the application of MO-ZnO NPs in biomedicine, environmental protection, and cosmetics, supporting an eco-friendly approach to advancing nanotechnology. This green synthesis method represents a step toward sustainable nanoparticle production, with potential benefits across various scientific and industrial fields.

2. Materials and methods

2.1 Synthesis of ZnO NPs

Synthesis procedure, 0.2 M of Zinc acetate dihydrate is mixed in double distilled water and stirred in a magnetic stirrer continuously until the Zinc precursor is fully dissolved, creating a homogeneous solution. Slowly add a solution of Sodium hydroxide (NaOH) to the Zinc solution. The pH of this solution was adjusted to 10 using NaOH and continuously stirred for 1h to make a homogeneous mixture. Then being dried at 100 °C in a hot air oven. The dried ZnO powder underwent calcination at 350 °C for 2h in a muffle furnace. After cooling, a light white ZnO nano-powder was obtained.

2.1 Green synthesis of *Moringa oleifera*-Zinc Oxide Nanoparticles (MO-ZnO NPs)

In a typical MO-ZnO NPs synthesis process, Fresh MO leaves were dried for 10 days. Following that, the leaves were mashed into a fine powder. 5 grams of MO powder was mixed in distilled water and stirred continuously at a temperature of 60°C. After heating, the mixed solution was permitted to cool to ambient temperature and then filtered to obtain a clear MO leaf extract. A 0.2 M solution of Zinc precursor was prepared by dissolving it in distilled water. The filtered MO extract was added to the Zinc acetate dihydrate solution in a 1:1 volume ratio while stirred continuously. The pH of this solution was adjusted to 10 using NaOH and continuously stirred for 1h to make a homogeneous mixture. They were dried at

100 °C in a hot air oven. The dried MO-ZnO powder underwent calcination at 350 °C for 2h in a muffle furnace. After cooling, a MO-ZnO nano-powder was obtained.

3. Results and Discussion

3.1 X-Ray Diffraction

The ZnO NPs and ZnO NPs with MO leaf extract and the structure of hexagonal-wurtzite was verified using X-ray diffraction. For pure ZnO NPs, the main diffraction peak appeared at 2θ angles of 31.25°, 34.87°, 36.62°, 47.89°, 56.22°, 62.90°, 66.24°, 67.54°, and 68.34°, corresponding to the (100), (002), (101), (102), (110),(103), (200), (112), (201) planes, for the green-synthesized ZnO NPs the prominent peaks observed at angles of 31.18°, 34.53°, 36.37°, 47.07°, 56.44°, 62.98°, 66.40°, 67.58° and 68.87° correspond to the same plane (100), (002), (101), (102), (110), (103), (200), (112), (201). In green synthesis ZnO one extra peak due to the plane (001) was obtained at 2θ value at 27.82°, organic compounds or biomolecules from the MO leave extract could also contribute to the extra peak [4,7]. The pure ZnO NPs and green-synthesized ZnO NPs correspond to the hexagonal-wurtzite phase which is the common phase of ZnO [11].

By using the Scherrer equation the mean crystallite size was calculated

$$D = K\lambda / \beta \cos \theta$$

Where:

D - average crystallite size (nm)

K - Scherrer constant (typically taken as 0.9)

λ - X-ray wavelength

β - full width at half maximum (FWHM) of the peak in radians

θ - diffraction angle

The mean crystalline size for pure ZnO NPs is 25 nm and the crystalline size for biosynthesized ZnO NPs is 24 nm. The smaller crystalline size in leaf extract produced by ZnO NPs is by their natural capping agent [12] such as polyphenols, flavonoids, proteins, and carbohydrates [8] that act as reducing agents during the nanoparticle formation process. These capping agents stabilize the nanoparticles by preventing their agglomeration and controlling their growth during synthesis [3,9]. This results in smaller crystallites. In chemical synthesis, the growth of nanoparticles is usually driven by chemical precursors and physical conditions like pH, and reaction time, and the lack of natural capping agents like those in green synthesis might result in larger crystalline sizes [5,12,13].

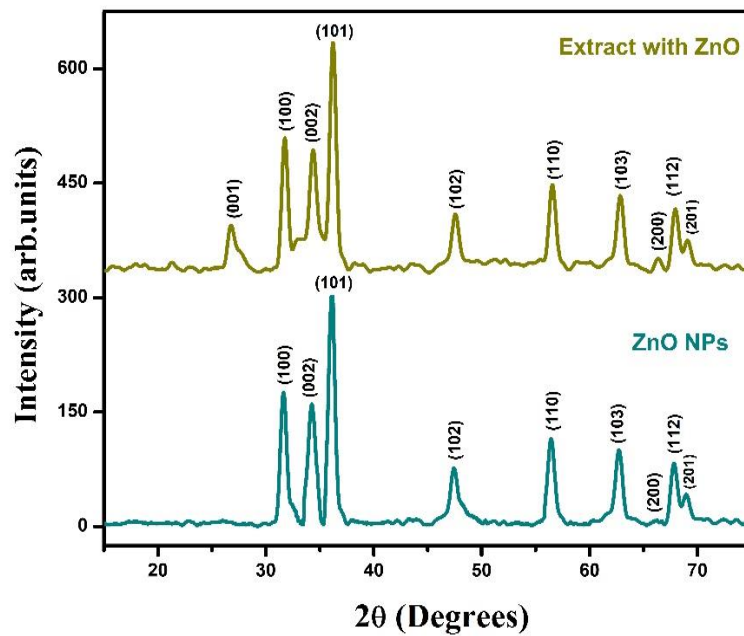


Fig. 1. XRD pattern of the synthesized ZnO NPs and MO leaf extract with ZnO NPs

3.2 Fourier Transform Infrared Spectroscopy (FT-IR)

Utilizing FT-IR spectroscopy the functional group was identified on their surface and identified how the ZnO NPs and the green-synthesized ZnO NPs were formed. However, the ZnO NPs and MO extract ZnO NPs were recorded in the 4000 cm^{-1} to 400 cm^{-1} regions. Fig.2. compares the ZnO NPs FT-IR spectrum with that of green-produced ZnO NPs and tabulated in Table 1.

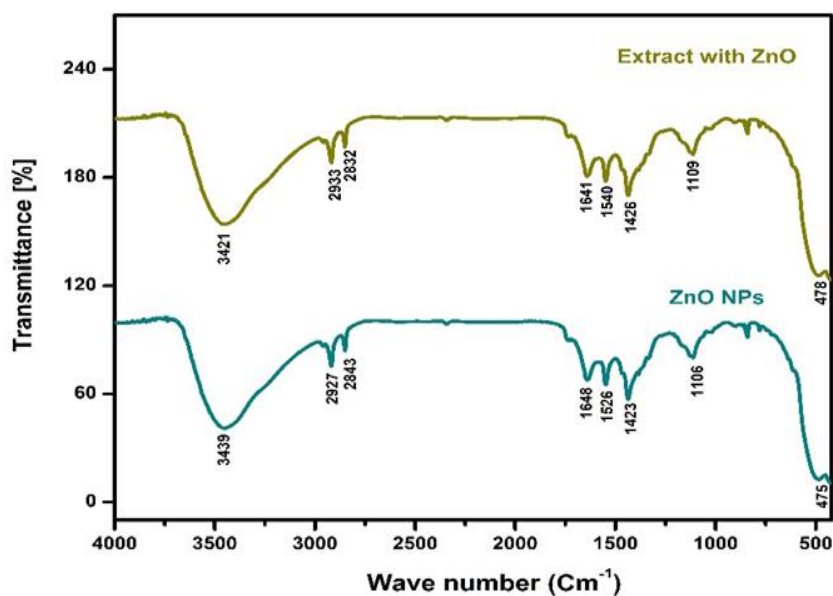


Fig. 2. FT-IR spectrum of synthesized ZnO NPs and *Moringa oleifera* leaf extract with ZnO NPs

Table. 1. shows the Peak position and functional group of synthesized ZnO NPs and Extract with ZnO NPs

Peak Position (cm ⁻¹)		Functional Groups
ZnO NPs	Extract with ZnO NPs	
3439	3421	O-H Stretching
2927	2933	C-H Stretching
2843	2832	C-H Stretching
1648	1641	C=O Stretching
1526	1540	C-H Bending
1423	1426	C-H Bending
1106	1109	C-O Stretching
475	478	Zn-O Stretching

The environmentally friendly ZnO NPs FT-IR spectra displayed a minor shift marginally altered in peaks, indicating that the extract's main biomolecules had bound to ZnO NPs surface [13].

3.3 UV-Visible Spectroscopy (UV-Vis)

UV-Vis Analysis of ZnO and MO extract synthesized ZnO NPs are illustrated in Fig. 3, the produced ZnO NPs absorption spectrum shows that the peak is 370 nm, and the absorption spectrum of the produced green-synthesized ZnO NPs with the absorption peak is 374 nm. Higher UV absorption of green-synthesized ZnO NPs than the ZnO NPs is primarily due to their smaller crystalline size, the increased surface area-to-volume ratio [14], and surface interactions with biomolecules [15], all of which contribute to the enhanced light absorption in the UV region.

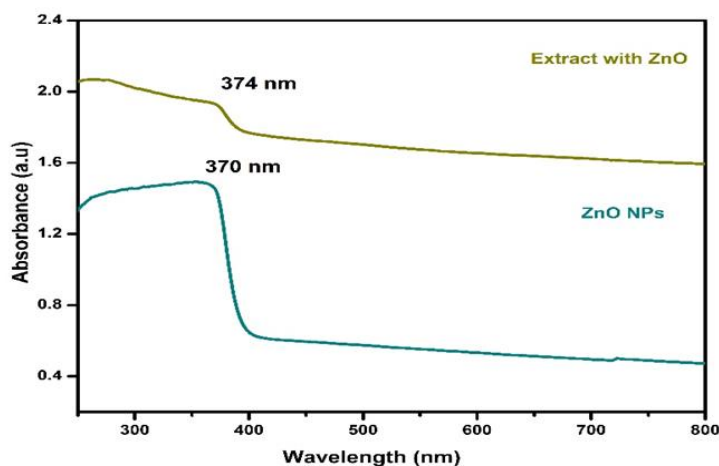


Fig. 3. UV-Visible analysis of synthesized ZnO NPs and MO leaf extract-ZnO NPs

4. Conclusion

ZnO NPs' environmentally friendly production employing MO leaf extract demonstrates a sustainable approach to nanoparticle production. The green synthesised MO-ZnO NPs show higher absorption. The use of MO leaf extract not only underscores the green synthesis methods but also promotes natural resources, reducing the reliance on harmful chemical processes. Future research could focus on optimizing the synthesis parameters of MO-ZnO NPs further and exploring their efficacy in specific applications, thereby advancing the development of environmentally friendly nanomaterials.

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Green Synthesis and Electrical Characterization of Copper Ferrite Nanomaterials using Egg White as fuel

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ABSTRACT

Cubic spinel ferrites are essential magnetic metal oxide materials with applications in data storage, adsorption, sensors, and innovative technologies. Among them, nano zinc ferrite is particularly valuable owing to its strong photo-induced catalytic activity, low saturation magnetization, increased resistivity, and consistent properties. In this study, CuFe_2O_4 nanoparticles were produced by means of a green solution combustion technique with egg white as a bio-template fuel. The produced nanoparticles were evaluated for their structural and electrical properties. XRD analysis confirmed the development of copper ferrite with reduced crystallite size, while FTIR spectroscopy identified the chemical bonds within the nanomaterial. Dielectric analysis was conducted to assess the electrical characteristics by measuring dielectric permittivity and loss over a broad frequency range. This analysis is crucial for understanding polarization processes, conductivity, relaxation mechanisms, and molecular dynamics. Electrical characterization techniques are widely applied in electronics, material science, and research for comprehensive material evaluation.

Keywords: conductivity, dielectric, ferrite, FTIR, XRD

1. Introduction

Magnetic nanoparticles are small particles, typically on the nanoscale (1-100 nanometers in size), that exhibit magnetic properties. They have been extensively researched for their unique magnetic, electrical, optical properties [1] and potential applications such as biomedical Imaging [2], Drug Delivery [3], cancer therapy [3], environmental remediation [4], catalyst [5], and biotechnology [6]. They are frequently made from materials like iron, nickel, cobalt, or their alloys. Spinel ferrite nanoparticles hold significant importance in the realm of magnetic nanoparticles due to their distinct characteristics and versatile applications. Spinel ferrite is a specific class of ferrite materials that have a crystal structure known as spinel. This structure is characterized by an arrangement of metal cations (ions with a positive charge) in a pattern where they reside at specific locations within the crystal lattice. The typical chemical formula for a spinel ferrite is represented as $\text{M}^{2+}\text{Fe}_2^{3+}\text{O}_4$ where M^{2+}

represents a divalent metal cation such as zinc (Zn), copper (Cu), or magnesium (Mg). Fe^{3+} denotes two trivalent metal cations denoting two trivalent metal cations. O_4 stands for four oxide ions that complete the crystal structure. The M^{2+} and Fe^{3+} cations will be dispersed among the tetrahedral and octahedral crystal sites of the spinal structure [7]. In our work CuFe_2O_4 is produced by combining egg white (albumen) with the nitrates of iron and copper. Being magnetic materials, copper ferrite nanoparticles can display superparamagnetic behavior, rendering them useful for various applications like targeted drug delivery and magnetic resonance imaging (MRI). These nanoparticles find use in various fields, including electronics, materials science, medicine, and environmental science, showcasing their versatility.

After a thorough analysis of solid-state reactions, this approach was selected. Nanoparticle synthesis employs a range of techniques, including chemical reduction, sol-gel processes, precipitation, and physical means such as laser ablation or milling. These methods are utilized to create particles with specific properties, sizes, and shapes, catering to diverse applications in fields like medicine, electronics, catalysis, and more. Green synthesis offers numerous advantages compared to traditional synthesis methods. It is more environmental friendly and operates at a low reaction temperature, reducing the use of toxic chemicals, energy, and generating less waste. This approach aims to reduce the use of harmful chemicals and energy in the mixture process, making it more eco-friendly. It's gaining attention due to its reduced environmental impact and potential for diverse applications in various industries. It often utilizes natural, renewable materials like plant extracts, animal byproducts, microorganisms such as fungi and bacteria, or other sustainable resources [8]. Santi Maensiri et al. initially documented the albumen-enriched egg white for the synthesis of ferrites substituted for transition metal [9]. The ultimate goal of the present work is to examine the physical, chemical and electrical characteristics of copper ferrite.

2. Experimental details

Copper ferrite nanoparticles were prepared using highly pure ferric nitrate nonahydrate, cupric nitrate hexahydrate, and freshly processed egg white. Egg white is noted for its foaming and emulsification capabilities and being water-soluble, making it easy to interact with metal ions [9,10]. Egg white is also a binding agent and gel for material shaping.

In the synthesis process, 45 mL of egg white was mixed with 5 mL of distilled water and stirred thoroughly using a magnetic stirrer for approximately 30 minutes. Copper nitrate and ferric nitrate are mixed in a stoichiometric ratio of 1:2 with distilled water to prepare a 50

ml solution. This mixture is stirred using a magnetic stirrer until a clear solution is achieved. After preparing the metal nitrate solution, it is added dropwise to the egg white solution while stirring continuously until froth forms, ensuring proper binding. The combined solution is then heated on a hot plate, which ignites a spark and initiates combustion, resulting in a fluffy product. Finally, the obtained product is calcined in a muffle furnace at 600°C for about 3.5 hours to achieve the desired material. Further, the synthesised material is subjected to various studies such as powder XRD, FTIR and dielectric studies.

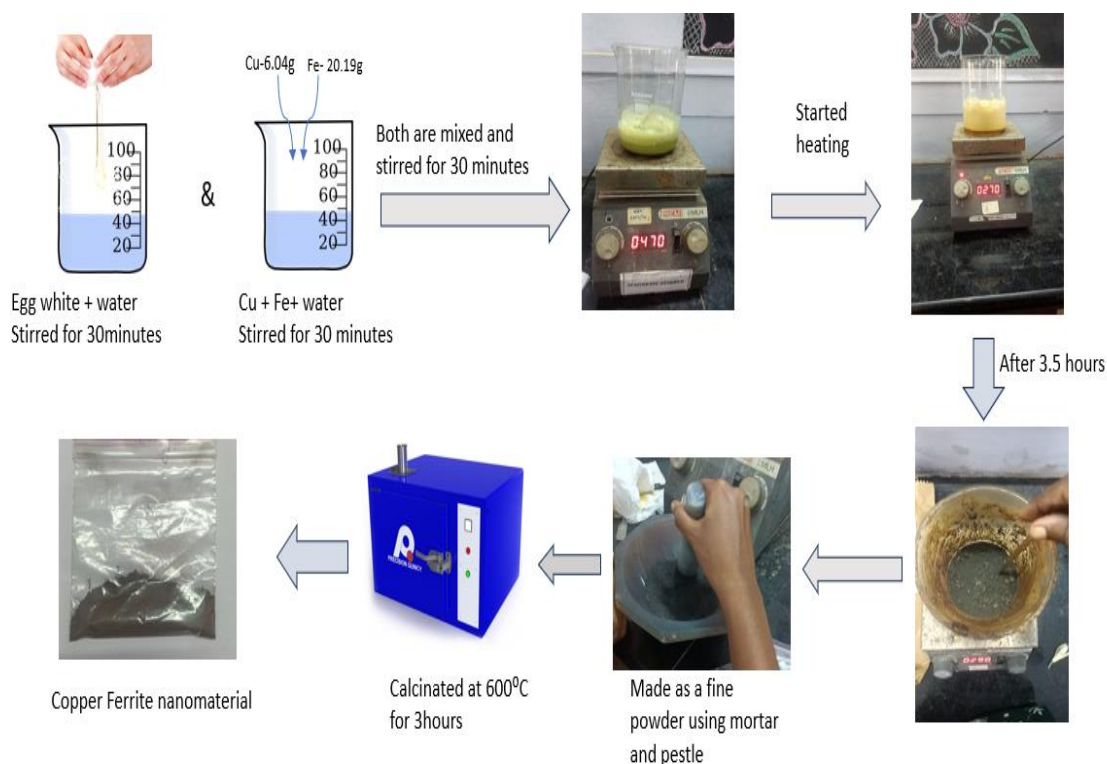


Fig. 1. Schematic representation of synthesis of copper ferrite nanoparticles

3. Results and Discussion

3.1. XRD Analysis

The synthesized copper ferrite nanoparticle was calcinated at 600°C for three hours and subjected to XRD analysis. The PXRD pattern of the prepared particles is shown in the figure. They exhibit typical reflection planes (2 2 0), (3 1 1), (4 0 0), (5 1 1), and (4 4 0) that are indicators of the presence of cubic spinel structure [11]. These diffraction planes serve as clear evidence of the formation of copper ferrite nanoparticles. All the diffraction peaks align closely with the expected values. (JCPDS file No: 25-0283). The mean particle size of CuFe_2O_4 nanoparticle is found to be 50.17631 nm using Scherrer equation. $D = K\lambda/\beta\cos(\theta)$, where: D is the crystallite size, K is shape factor (typically around 0.9), β is the FWHM of the

peak in radians, λ is the X-ray wavelength and θ is the Bragg angle. The lattice parameter of CuFe_2O_4 nanoparticle is calculated to be 8.4009\AA using the below formula [12, 13]

$$a = d\sqrt{h^2 + k^2 + l^2}$$

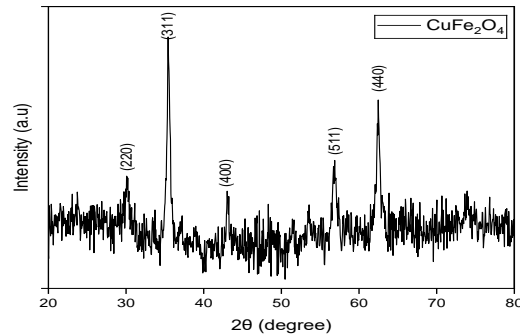


Fig. 2. XRD pattern of CuFe_2O_4 nanoparticle

3.2. FTIR Analysis

The FTIR bands of copper ferrite nanoparticles were analysed in two ranges of the absorption bands, $4000 - 1000\text{ cm}^{-1}$ and $1000-400\text{ cm}^{-1}$ and shown in Figure. In the range of $4000 - 1000\text{ cm}^{-1}$, vibrations of CO, NO and moisture were observed. The intense broad band around 3436 cm^{-1} and the less intense band near 1617 cm^{-1} are attributed to O-H stretching vibrations interacting through hydrogen bonds. The $\nu(\text{C}=\text{O})$ stretching vibration of the carboxylate group (CO_2) appears around 1383 cm^{-1} , while the band at approximately 1096 cm^{-1} corresponds to traces of nitrate ions [14-16].

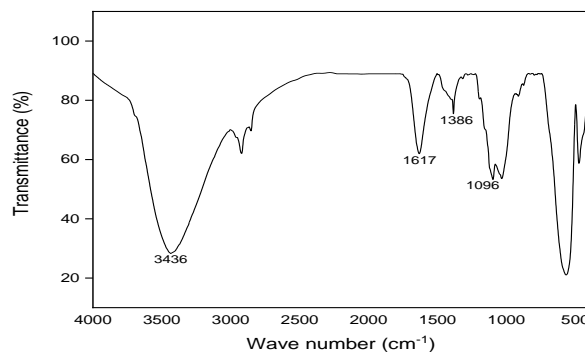


Fig. 3. FTIR spectra of CuFe_2O_4 nanoparticle

3.3. Dielectric Analysis

The dielectric constant (ϵ_r) of CuFe_2O_4 was determined through dielectric analysis. The capacitance of a parallel plate capacitor, formed by electrodes with the sample as the dielectric medium, was measured. The capacitance variation was observed across a frequency

range of 100 Hz - 1 MHz at temperatures between 40°C and 150°C. The dielectric constant (ϵ_r) of the material was calculated at diverse temperatures using the measured capacitance values. It was determined using the following equation. [17]

$$\epsilon_r = \frac{tC_p}{A\epsilon_0}$$

Here, t represents the thickness of the sample, C_p is the measured capacitance, ϵ_0 is the permittivity of free space, and A denotes the sample's area. The variation of the dielectric constant with frequency at different temperatures for CuFe_2O_4 nanoparticles is illustrated in Fig. 4. It is evident from Fig. 4 that the dielectric constant decreases as the temperature increases. [18-20]

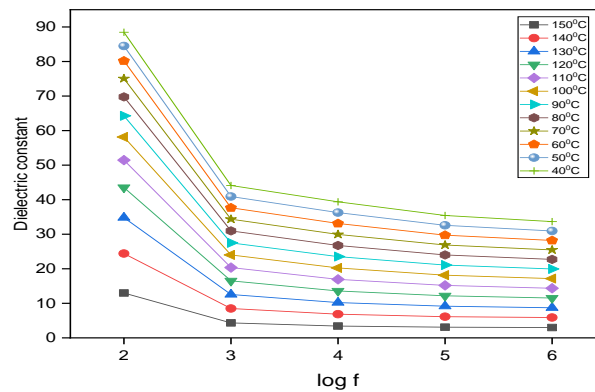


Fig. 4. log f Vs Dielectric constant

The AC Conductivity is calculated using the given relation.

$$\sigma_{ac} = \omega\epsilon_0\epsilon' \tan\delta$$

Where, σ_{ac} is the AC Conductivity, ϵ_0 is the permittivity of free space, ω is the angular frequency and δ is the loss factor. The plot depicting the discrepancy of AC conductivity with frequency is shown in Fig 5. It is detected that the AC conductivity increases with both the applied frequency and temperature [21]. The rise in AC conductivity can be ascribed to enhanced polarization effects, which is due to the increased mobility of free charges as the temperature increases.

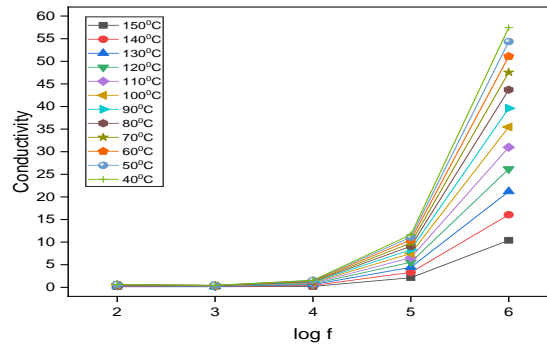


Fig. 5. log f Vs AC Conductivity

The plot illustrating the discrepancy of dielectric loss versus frequency is presented in Fig. 6. The dielectric loss declines as the frequency increases; however, it shows an cumulative trend with a rise in temperature [22,23].

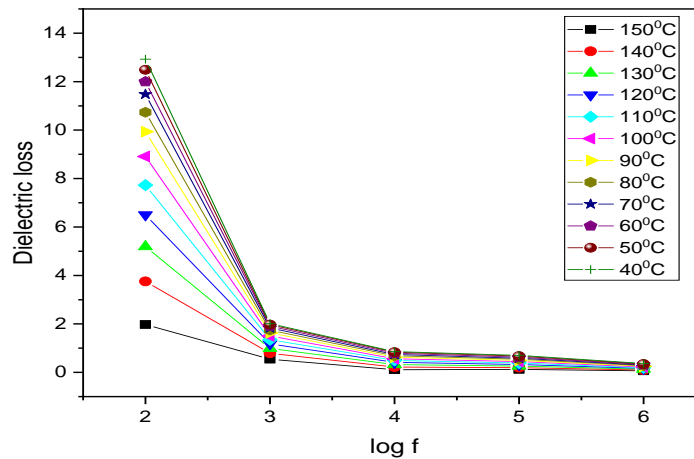


Fig. 6. log f Vs Dielectric loss

4. Conclusion

The present work focuses on the synthesis of Copper Ferrite nanoparticles in green synthesis route using egg white as an eco-friendly precursor. The egg white protein albumen served as a fuel in the auto combustion method. Characterization techniques such as PXRD, FTIR, and dielectric measurements were conducted to investigate the structural, elemental, and dielectric properties of the materials. PXRD analysis confirmed the formation of copper ferrite (CuFe_2O_4) nanoparticles with a cubic spinel structure and an average particle size of 50.176 nm. The FTIR spectra displayed absorption peaks at 466 cm^{-1} and 567 cm^{-1} , indicative of metal-oxygen vibrations. Dielectric studies revealed that both the dielectric constant and dielectric loss decrease with increasing frequency of the applied signal, while the AC conductivity increases with frequency. These synthesized copper ferrite nanoparticles exhibit potential applications in electronics and energy storage.

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Electronic Band Structure and Density of States of Alkali metals Rubidium and Cesium

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ABSTRACT

The electronic band structure, density of states and the behaviour of conduction and valence bands in body-centered cubic rubidium and cesium, particularly under varying pressure conditions. The research examines how rubidium's and cesium's lattice constant and pressure change with reduced volume, providing insights into its structural properties. Furthermore, the distribution of electron energy levels is analysed through the density of states across different energy regions. In the Brillouin zone, the conduction and valence band widths are mapped across important symmetry sites and computed in relation to the Fermi level.

Keywords: Alkali metals, Band Structure, Density of States

1. Introduction

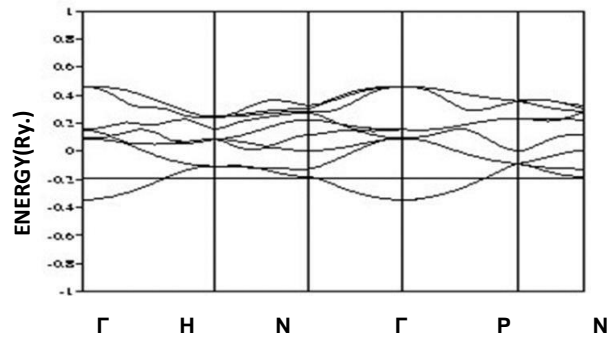
Rubidium (Rb) and cesium (Cs) are alkali metals with comparable chemical characteristics, including low ionization potentials and strong reactivity. Both elements have unique electronic structures that significantly impact their behaviour under various conditions. Understanding their conductive characteristics and how they react to changes in pressure requires knowledge of their electronic band structures and density of states (DOS). This study focuses on the electronic band structure and DOS of cesium and rubidium, using the Full-Potential Linear Muffin-Tin Orbital (FP-LMTO) method to explore their behaviour under different pressures.

2. Band Structure

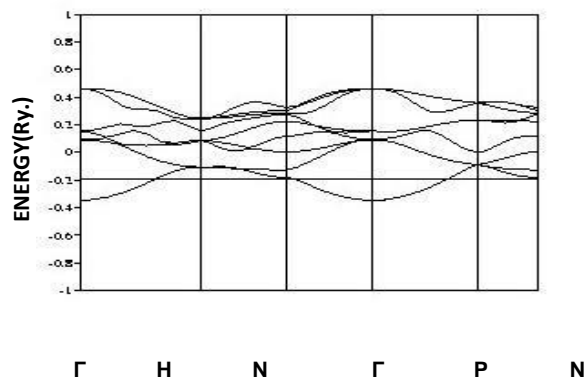
An illustration of the energy levels that electrons in a material can inhabit is provided by the electronic band structure. Cesium, being a metal, exhibits overlapping conduction and valence bands, which is characteristic of metallic elements. This overlap allows for the free movement of electrons, contributing to its high conductivity. Rubidium, while similar in behavior to cesium, exhibits slight differences in the overlap of its conduction and valence bands, based on the FP-LMTO computations.

For both cesium and rubidium, the band structures were calculated along key

symmetry directions in the Brillouin zone: Γ -H-N- Γ -P-N. The metallic character of the conduction and valence bands was confirmed by the Fermi level, which was situated between them. According to the band structure data for cesium, the 6s orbital is the primary source of the conduction band, where rubidium's conduction band also features contributions from the 5s orbital, but the overlap with the valence band is somewhat less pronounced than in cesium.



CESIUM



RUBIDIUM

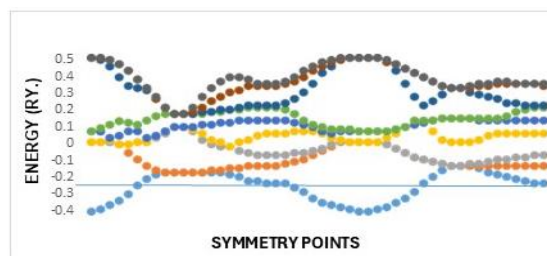


Fig. 2. Band structure of cesium using M.S. Excel

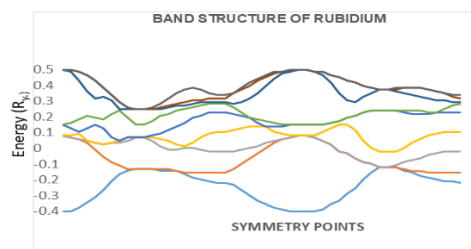


Fig. 3. Band Structure of rubidium using M.S. Excel

Graphs of the band structures for cesium and rubidium show that, as pressure increases and the reduced volume decreases, the bands shift accordingly. This shift in the band structure is a reflection of how the material's lattice constants and reaction to external forces have changed.

3. Density of States

The quantity of electronic states that can be occupied at each energy level is measured by the density of states (DOS). For cesium and rubidium, the DOS was calculated across various energy levels, disclosing important comprehension into their electronic structures. Both metals show significant peaks in the DOS near the Fermi level, providing evidence of a high density of states at the energy levels most likely to be occupied by electrons.

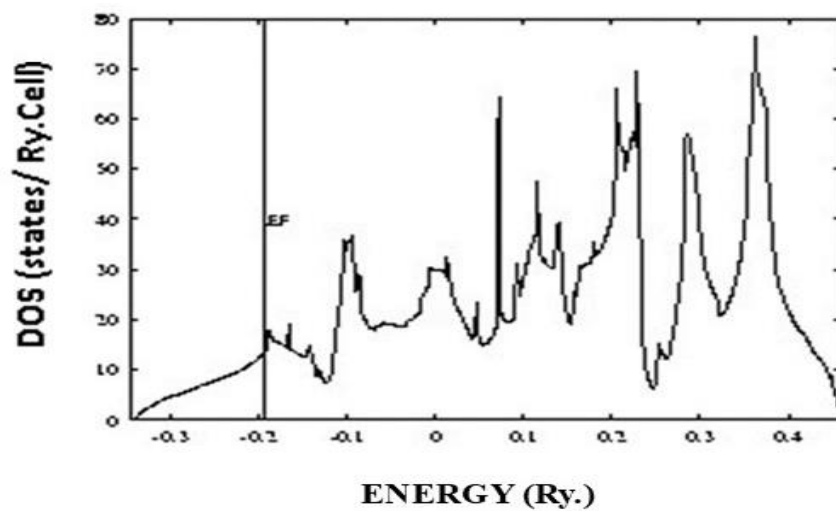


Fig. 4: Density of States of Cesium using FP-LMTO method.

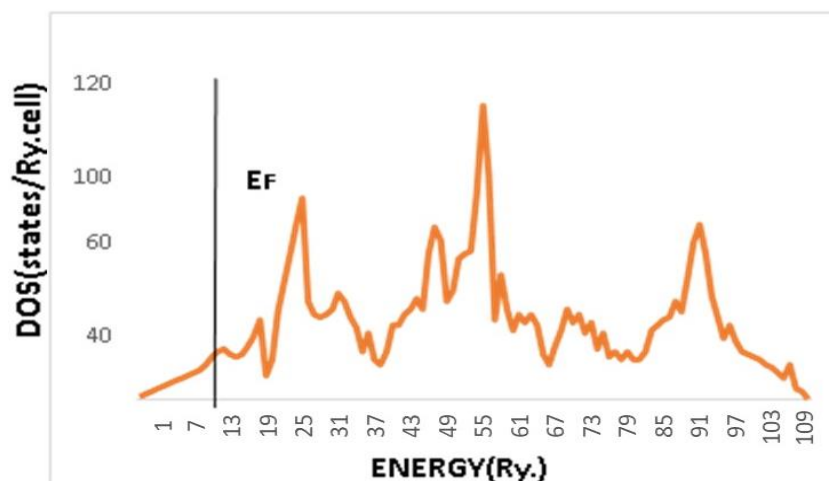


Fig. 5: Density of States of Cesium using M.S. Excel

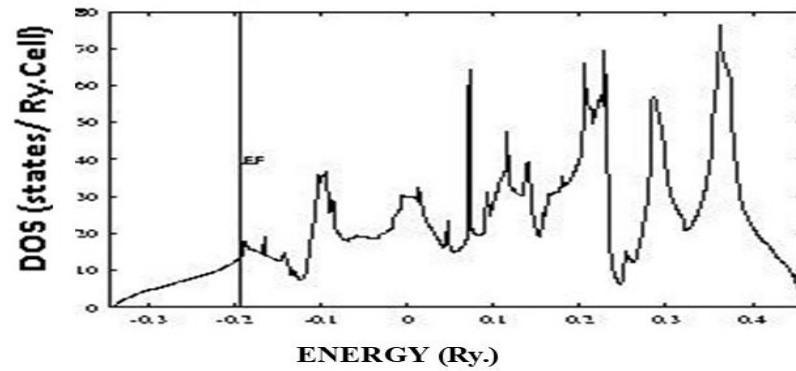


Fig. 6: Density of States of Rubidium using FP-LMTO method.

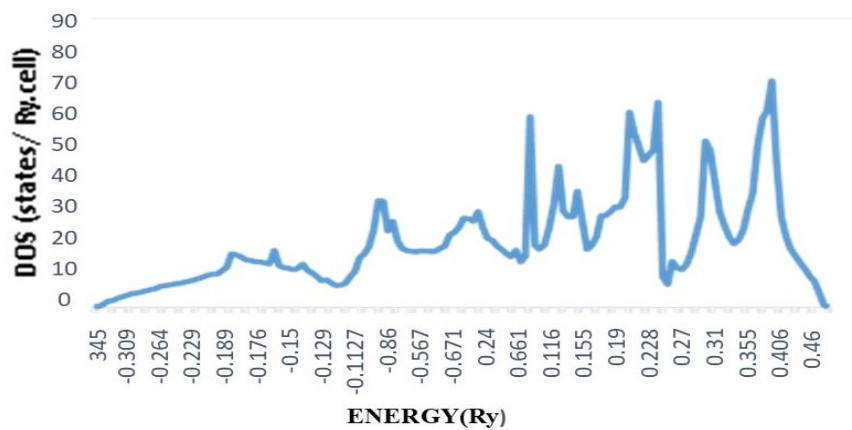


Fig. 7: Density of States of rubidium using M.S. Excel

The DOS for cesium is characterized by a broad distribution, with significant contributions from the 6s orbital, while rubidium's DOS has a more localized distribution, primarily stemming from its 5s and 4d orbitals. The increased electron density at the Fermi level in cesium suggests stronger metallic behavior compared to rubidium.

For both cesium and rubidium, the DOS shows a pronounced shift in the peak positions as pressure is applied, reflecting the changes in their electronic environments under different volume conditions.

4. Ground State and Its Properties

The total energy as a function of decreased volume (V/V_0) was used to study the ground state characteristics of cesium and rubidium, using the Murnaghan equation of state. The results showed that as the reduced volume decreases, the total energy increases for both metals, indicating an increase in internal pressure.

For cesium, the equilibrium lattice constant is 11.427 Å at normal pressure. As the pressure increased, the lattice constant decreased, confirming the typical behavior of alkali metals under pressure. The pressure values at various reduced volumes were also computed,

and it was observed that as the lattice constant increases, the pressure decreases.

Rubidium's ground state properties showed similar trends, however the particular numbers for lattice constant and pressure were somewhat lower than those for cesium, reflecting differences in their atomic radii and bonding characteristics.

5. Conclusion

This study provides a detailed analysis of the electronic band structure and density of states of cesium and rubidium, with a focus on how these properties evolve under pressure. The findings confirm that both cesium and rubidium exhibit metallic behaviour, with overlapping conduction and valence bands. Cesium has a larger density of states around the Fermi level, indicating stronger metallic properties than rubidium. The ground state study indicated typical alkali metal behavior, with decreasing lattice constant and increasing pressure as volume is lowered. These findings contribute to the understanding of cesium and rubidium's electronic structures and provide a foundation for future studies on these metals under varying pressure conditions.

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Evaluation of Antioxidant Potentials of Benzimidazoles Synthesized from *Ortho*-Phenylenediamine and Benzaldehyde Derivatives Via *Phyllanthus emblica* Fruit Extract

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ABSTRACT

The present investigation concentrates the antioxidant potentials of two benzimidazole derivatives synthesised from o-phenylenediamine, 3-nitrobenzaldehyde and 3-fluorobenzaldehyde using Phyllanthus emblica fruit extract. Benzimidazoles synthesised from Phyllanthus emblica extract are confirmed from the spectral studies. Antioxidant property of benzimidazole derivatives is identified from DPPH assay process. The IC₅₀ of control ascorbic acid and benzimidazoles synthesised from o-phenylenediamine and 3-nitrobenzaldehyde and ortho-phenylenediamine and 3-fluorobenzaldehyde are 97.12, 80.23 and 92.23 µg/mL. The results suggested that the two synthesised benzimidazole derivatives show very good antioxidant activities. Thus, the green synthesised benzimidazole derivatives make a path for future research in clinical diagnosis as antioxidants and therapeutic agents.
Keywords: Antioxidant activity, Benzimidazole. Green synthesis, Phyllanthus emblica extract

1. Introduction

Chemical reactions carried out without solvents enhance efficiency, selectivity, manipulation ease, and often avoid toxic and volatile solvents. For the increasing economic and environmental concerns in recent years, it is now essential for chemists to search for as many environmentally benign methods as possible. The edible plants, fruits, roots and leaf extracts can be used in biocatalytic transformation for organic reactions [1,2]. Benzimidazole is a heterocyclic aromatic organic compound, beneficial pharmacophore and a prerogative structure in medicinal chemistry. Benzimidazole and its derivatives act as therapeutic agents and its shows various biological activities viz antiulcer, antihypertensive, analgesic, anti-inflammatory, anti-viral, antifungal, anticancer, and antihistaminic agents [3-5].

Nowadays, fruit and plant extracts have been recognised as viable organic solvent for synthesizing compounds of pharmaceutical interest [6]. It is used as solvent and catalyst in numerous reactions [7]. The broad application of various fruit extracts is attributed to its harmless, cost-effective, and environmentally friendly properties. Additionally, bioactive

compounds isolated from the waste of fruits and vegetables play a substantial role in organic synthesis [8].

According to the review of literature, the present study concentrates on the natural acid catalysed solvent free synthesis of benzimidazole derivatives from *o*-phenylenediamine, 3-nitrobenzaldehyde and 3-fluorobenzaldehyde using *Phyllanthus emblica* fruit extract. *Phyllanthus emblica* often known as Indian gooseberry has become extremely important in indigenous traditional medical systems. The fruit of *Phyllanthus emblica* contains various phytochemicals, fatty acids, glycosides and phosphatides. This extract is used as the reagent for benzimidazole derivatives synthesis. The synthesised benzimidazole derivatives are confirmed by spectral analysis (absorption and FT-IR). The benzimidazole derivatives show good antioxidant potentials.

2. Materials and Methods

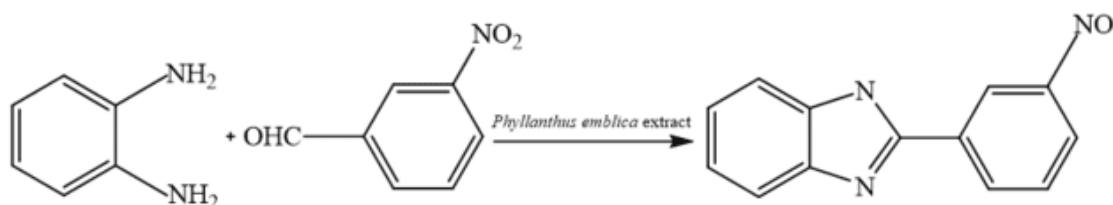
Fresh and ripened *Phyllanthus emblica* fruit was purchased from the market. The chemicals *o*-phenylenediamine, 3-nitrobenzaldehyde and 3-fluorobenzaldehyde were procured from Merck.

2.1. Preparation of *Phyllanthus emblica* extract

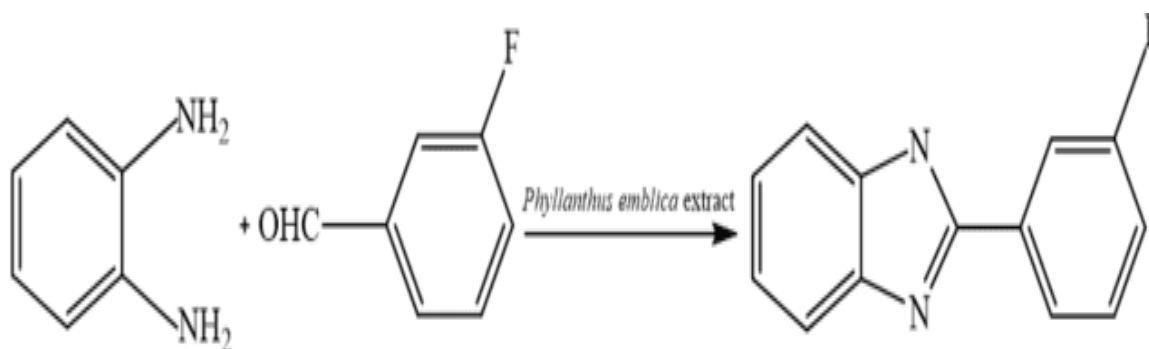
About 50 g of ripened *Phyllanthus emblica* fruit was washed thoroughly by water and cut into small pieces. The pieces were grinded by a mixer grinder and filtered *via* Whatman filter paper. The collected filtrate was centrifuged around 15 min. The collected centrifugate was then used for synthesis of benzimidazole derivatives.

2.2 Synthesis of Benzimidazole Derivatives from *Phyllanthus emblica* extract

Equal quantities of *o*-phenylenediamine, 3-nitrobenzaldehyde and 5 mL of the extract were placed in a mortar and grinded well for 1 h using a pestle. The corresponding benzimidazole product was separated out as a pale orange paste (**Scheme 1**). The product was washed by ice water and purified by recrystallization with a minimum amount of ethanol. Similarly, benzimidazole from *o*-phenylenediamine and 3-fluorobenzaldehyde was also synthesised (**Scheme 2**).



Scheme 1. Synthesis of benzimidazole from *o*-phenylenediamine and 3-nitrobenzaldehyde



Scheme 2. Synthesis of benzimidazole from *o*-phenylenediamine and 3-fluorobenzaldehyde

2.3 Characterization Methods

The UV-Visible spectra of benzimidazoles were taken from the Shimadzu UV-1800 spectrophotometer. FT-IR spectrum of the samples was analysed by Shimadzu IR Affinity spectrophotometer using KBr pellet method.

2.4 Antioxidant Activity

Antioxidant efficiency of benzimidazole derivatives was assessed by the DPPH assay method. Antioxidant properties of benzimidazole derivatives at different concentrations (10 - 500 µg/mL) were determined and the results are compared with the control ascorbic acid.

$$\% \text{ of Inhibition} = \frac{[\text{Abs of control} - \text{Abs of test}]}{\text{Abs of control}} \times 100$$

A plot of % inhibition *vs* concentration was drawn and the IC₅₀ value was calculated from the plot.

3. Results and Discussion

The role of *Phyllanthus emblica* extract for the synthesis of benzimidazoles from *o*-phenylenediamine and 3-nitrobenzaldehyde and *o*-phenylenediamine and 3-fluorobenzaldehyde is analysed. The benzimidazole derivatives are characterized by absorption and IR spectral methods. *Phyllanthus emblica* extract contains citric acid and ascorbic acid, the acids present in the extract catalysed the preparation of benzimidazole derivatives.

3.1 Absorption Spectral Studies

The synthesized benzimidazoles from *Phyllanthus emblica* extract is first analyzed by absorption spectral studies. The UV-Visible spectrum of benzimidazoles is carried out in ethanol. The benzimidazole synthesised from *o*-phenylenediamine and 3-nitrobenzaldehyde displays bands at 255.5, 262, 268.5 and 285 nm (**Figure 1**) whereas the benzimidazole synthesised from *o*-phenylenediamine and 3-fluorobenzaldehyde displays bands at 262, 264.5, 268 and 305 nm due to π - π^* and n - π^* transitions (**Figure 2**).

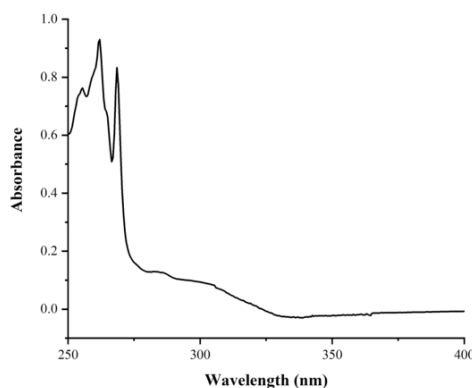


Figure 1. UV spectrum of benzimidazole from *o*-phenylenediamine and 3-nitrobenzaldehyde

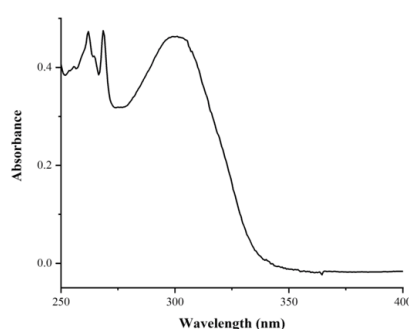


Figure 2. UV spectrum of benzimidazole from *o*-phenylenediamine and 3-fluorobenzaldehyde

3.2 FT-IR Spectral Studies

The FT-IR spectrum of benzimidazole derivative synthesised from *o*-phenylenediamine and 3-nitrobenzaldehyde using *Phyllanthus emblica* extract displays bands in the region 3402, 2980, 2899, 2378, 1924, 1651, 1396, 1328, 1263, 1051, 881, 659 cm^{-1} respectively (**Figure 3**). The broad band occurs at 3402 cm^{-1} indicates N-H stretching of secondary amine. The band at 2980 cm^{-1} indicates aromatic C-H stretching. The band forms at 1651 cm^{-1} demonstrates C=N stretching of benzimidazole ring. The band at 1328 cm^{-1} represents C-N stretching of the benzimidazole ring. The band at 1396 cm^{-1} indicates NO_2 stretching of an asymmetric ring. The band at 1263 cm^{-1} represents NO_2 stretching of the symmetric ring. The band at 659 cm^{-1} indicates N-H stretching. The formation of benzimidazole derivatives from *o*-phenylenediamine and 3-nitrobenzaldehyde is thus confirmed from the FT-IR spectral information.

FT-IR spectrum of benzimidazole derivative synthesised from *o*-phenylenediamine and 3-fluorobenzaldehyde using *Phyllanthus emblica* extract displays bands at 3466, 3194, 2526, 2382, 1687, 1627, 1589, 1517, 1346, 1220, 1132, 1082, 974, 910, 738, 696, 553 cm^{-1} respectively (**Figure 4**). The broad band occurring at 3466 cm^{-1} represents N-H stretching of the imidazole ring (N-H). The band formed at 3194 cm^{-1} indicates C-H

stretching of the aromatic ring. The bands arise at 1687 and 1627 cm^{-1} demonstrates C=N stretching of benzimidazole ring. The bands at 1589 and 1517 cm^{-1} indicates aromatic C=C stretching. The bands occur at 1346 and 1220 cm^{-1} represent aromatic C-N stretching of the ring. The band at 1132 cm^{-1} indicates C-F stretching. The band at 1080 cm^{-1} represents aromatic C-H in-plane bending. The bands occur at 974 and 910 cm^{-1} indicate aromatic C-H out-plane bending. The bands at 738 and 696 cm^{-1} represent aromatic ring vibration. The band occurs at 553 cm^{-1} indicates C-N bending. The formation of benzimidazole derivatives from *o*-phenylenediamine and 3-fluorobenzaldehyde is thus confirmed from the FT-IR spectral information.

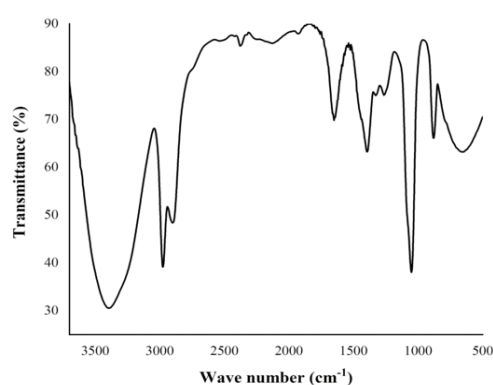


Figure 3. FT-IR spectrum of benzimidazole from *o*-phenylenediamine and 3-nitrobenzaldehyde

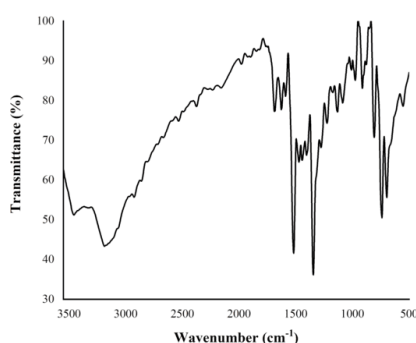


Figure 4. FT-IR spectrum of benzimidazole from *o*-phenylenediamine and 3-fluorobenzaldehyde

3.3 Antioxidant Potential of Benzimidazoles

Antioxidant potentials of benzimidazoles at various concentrations are presented in **Tables 1** and **2**. The synthesized benzimidazoles derivatives shows good antioxidant activity compared to that of ascorbic acid. The IC_{50} of ascorbic acid and benzimidazoles synthesised from *o*-phenylenediamine and 3-nitrobenzaldehyde and *o*-phenylenediamine and 3-

fluorobenzaldehyde are 97.12, 80.23 and 92.23 $\mu\text{g/mL}$. The antioxidant potential of benzimidazole derivatives mainly depends on the substituents present in the compounds. Thus, the present study confirms the antioxidant efficacy of two benzimidazole derivatives and these compounds can be used as good free radical scavengers.

Table 1. Percentage inhibition of benzimidazole from *o*-phenylenediamine and 3-nitrobenzaldehyde

Concentration ($\mu\text{g/mL}$)	Percentage of Inhibition (%)
Ascorbic acid	97.12
500	67.9489
250	60.7174
100	50.4621
50	47.5975
10	32.5338
IC₅₀	80.23 $\mu\text{g/mL}$

Table 2. Percentage inhibition of benzimidazole from *o*-phenylenediamine and 3-fluorobenzaldehyde

Concentration ($\mu\text{g/mL}$)	Percentage of Inhibition (%)
Ascorbic acid	97.12
500	72.9722
250	68.3493
100	59.1348
50	51.178
10	43.5401
IC₅₀	92.23 $\mu\text{g/mL}$

4. Conclusion

The antioxidant activities of two benzimidazole derivatives synthesised from *o*-phenylenediamine, 3-nitrobenzaldehyde and 3-fluorobenzaldehyde using the extract of *Phyllanthus emblica* has been investigated by DPPH assay method. The structure of the synthesised benzimidazole derivatives is confirmed from UV-Visible and FT-IR spectral techniques. The synthesised benzimidazoles show very good antioxidant activities when compared to ascorbic acid. This solvent-free method is eco-friendly and avoids the usage of harmful materials, making it a greener method for synthesizing benzimidazoles. The

antioxidant properties of benzimidazole derivatives are expected to stimulate further interest in biomedical applications.

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Green Synthesis of ZnO nanoparticles using *Solanum procumbens* leaf extract and its structural, optical and anti-inflammatory studies

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ABSTRACT

*The green synthesis approach utilizes natural plant extracts or biological sources, reducing the reliance on harmful chemicals and making it a more sustainable method for nanoparticle production. This method often involves readily available, low-cost plant materials, making it a more economical alternative to traditional chemical synthesis techniques. Nanoparticles which are synthesized using green methods exhibit enhanced biocompatibility, making them more suitable in pharmaceuticals and environmental remediation. The present investigation describes the synthesis of ZnO nanoparticles using *Solanum procumbens* leaf extract as the reducing agent. The synthesized ZnO nanoparticles were characterized by XRD, UV-Visible spectroscopy and FTIR techniques. The XRD pattern of the synthesized nanoparticles exhibited a wurtzite hexagonal structure of grain size 62 nm. The UV-Vis spectrum showed an absorption peak around 374 nm. By applying the Tauc method, the band gap energy of the ZnO nanoparticle was 3.30 eV. The anti-inflammatory activity of ZnO nanoparticles was determined using the Bovine serum albumin (BSA) denaturation assay at different concentrations of ZnO NPs, which showed inflammatory activity with the % of inhibition value of 92.72 $\mu\text{g/mL}$ at 250 mL concentration.*

Keywords: zinc oxide nanoparticles, green approach, anti-inflammatory, *Solanum procumbens*.

1. Introduction

In the past decade, the rapid advancement of nanotechnology across fields such as science, medicine, chemistry and biotechnology has led to the reduction of bulk materials to the nanoscale [1-4]. This miniaturization alters their structure and enhances their physico-chemical, optical properties [5]. Nanomaterials have found numerous applications, including drug delivery, bio-imaging, diagnostics, gene therapy, nanomedicine, bio-sensing, catalysis, photocatalysis, magnetic resonance imaging, cancer cell treatment, pharmaceuticals, and memory storage devices [6-8]. As the demand for nanoparticles with varying shapes and sizes grows, they can be synthesized through various methods, including irradiation, physical

techniques, chemical processes, and biological methods [9]. Common physical synthesis methods include microwave processing [10], solvo-thermal [11], and ultrasonic processing [12], while chemical methods like hydrothermal, sol-gel synthesis, laser ablation, and lithography are also widely used [13–17]. However, nanoparticles produced through chemical or physical means can pose risks in certain applications [18]. In contrast, nanoparticles synthesized using green methods are more eco-friendly, cost-effective, and biocompatible, making them suitable for large-scale production. Plant parts such as roots, stems, leaves, flowers, and fruits, which contain various phytochemicals, serve as stabilizing and reducing agents in the green synthesis of nanoparticles [19].

Among various metal nanoparticles, Zinc Oxide (ZnO) stands out for its significant applications in medicine and sensor technology. Zinc is known for its strong interaction with electromagnetism and its unique electronic properties. It serves as a cofactor in numerous catalytic and structural processes. ZnO nanoparticles are characterized by high electron mobility, a large exciton binding energy, a broad band gap, and excellent optical transmittance [20–21]. In the medical field, ZnO nanoparticles are widely used in products like sunscreen lotions, as well as for their therapeutic properties, including anti-inflammatory, wound-healing, anti-cancer, anti-fungal, antioxidant, and antibacterial effects [22–23].

In this work, the leaf extract of *Solanum procumbens* is used as a reducing agent for synthesizing ZnO nanoparticles. *Solanum procumbens*, a member of the Solanaceae family, has been utilized in traditional medicine for treating conditions like colds, coughs, asthma, and thyroid disorders. It is commonly used at home for relieving cold and cough symptoms. This plant is known for its anti-inflammatory, antioxidant, antipyretic, anticancer, anti-asthma, and antibacterial properties [24]. The liquid extract of *Solanum procumbens* has been found to contain a variety of bioactive compounds including flavonoids, steroids, coumarins and glycoalkaloids, triterpenoids, sugars, amino acids, saponins, phenolic compounds, and anthraquinones. Additionally, important chemical constituents such as sobatum, solanine, solasodine, and diosgenin are present [25].

2. Materials and Methods

Zinc acetate dihydrate and sodium hydroxide were obtained from Sigma–Aldrich, India. Fresh leaves of *Solanum procumbens* were harvested from Marthandam in Kanyakumari district.

2.1 Preparation of *Solanum procumbens* extract

Medicinal leaves of *Solanum procumbens* were collected from Kanyakumari District. The leaves were carefully washed, shade-dried, and ground into a fine powder. Ten grams of

the powdered leaves were mixed with distilled water (100 mL) and heated on a magnetic stirrer at 70°C for 30 min. The resulting solution was filtered, cooled and utilized for the synthesis of ZnO nanoparticles.

2.2 Synthesis of ZnO nanoparticles using *Solanum procumbens* leaf extract

About 25 mL of *Solanum procumbens* extract was mixed with zinc acetate and sodium hydroxide (1:2 molar ratio). The resulting yellow solution was stirred for 3 h and then left to stand undisturbed for 24 h. The resulting precipitate was washed with deionized water, and dried in a hot air oven at 250°C for 2 h. The synthesized zinc oxide nanoparticles were ground into a fine powder using a mortar for subsequent characterization.

2.3 Instrumentation

The particle size of the synthesized nanoparticles was determined from the XRD using a powder X-ray diffractometer with Cu K α radiation, covering a 2 θ range of 10° to 80°. The optical absorption spectrum of the nanoparticles was measured using a UV-visible spectrophotometer. FTIR spectroscopy was used to examine the functional groups present in the ZnO nanoparticles, using a PerkinElmer FTIR spectrometer. The anti-inflammatory efficacy of ZnO nanoparticles was evaluated through Bovine serum albumin (BSA) denaturation assay.

3. Results and Discussion

3.1 Structural studies of ZnO nanoparticles using *Solanum procumbens*

Structure and phase purity of ZnO nanoparticles using *Solanum procumbens* leaf extract are shown in Fig. 1. From the diffraction patterns, it is very well understood that it has a hexagonal phase (wurtzite structure) by comparison with the data from JCPDS card No. 89-1397[26], and no indication of a secondary phase or impurity peaks. The XRD pattern indicates the crystalline nature of the nanoparticles. The sharp, intense diffraction peaks appearing at 31.29°, 33.95°, 36.04°, 47.05°, 56.09°, 62.38°, 65.90°, 67.45°, 68.60°, 72.03°, and 76.48° correspond with those from (100), (002), (101), (102), (110), (103), (200), (112), (201), (004) and (202) orientations, respectively. The synthesized nanoparticles show a particle size of 62 nm which was calculated using Scherer's equation [27].

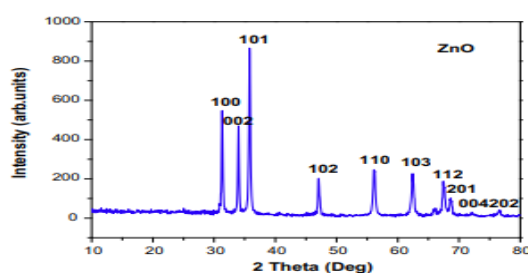


Figure 1 XRD pattern of synthesized ZnO sample using *Solanum procumbens*

3.2 Optical studies of synthesized ZnO nanoparticles using *Solanum procumbens* extract

UV-Vis spectroscopy was also conducted to confirm the formation of ZnO nanoparticles. In the absorption spectrum of synthesized nanoparticles (Figure-2), the peak was observed at 374 nm, which attributes to the intrinsic band-gap of ZnO absorption [28]. This absorption is associated with the intrinsic band-gap transition of ZnO, specifically the excitation of electrons. The observed peak at 374 nm corresponds to the characteristic UV absorption for ZnO, which has a wide band-gap typically ranging from 3.2 eV to 3.4 eV, depending on the size of the particle and synthesis conditions. This peak is indicative of the formation of ZnO nanoparticles and confirms their optical properties, with the specific wavelength being consistent with ZnO's well-known electronic structure. The position and peak intensity can also provide insights into the size and morphology of the ZnO nanoparticles, as quantum size effects often shift the absorption towards shorter wavelengths in smaller particles. The band gap of a material, which refers to the energy difference between the excitation bands, can be estimated using a Tauc Plot [29] and is 3.3 eV (Figure 3).

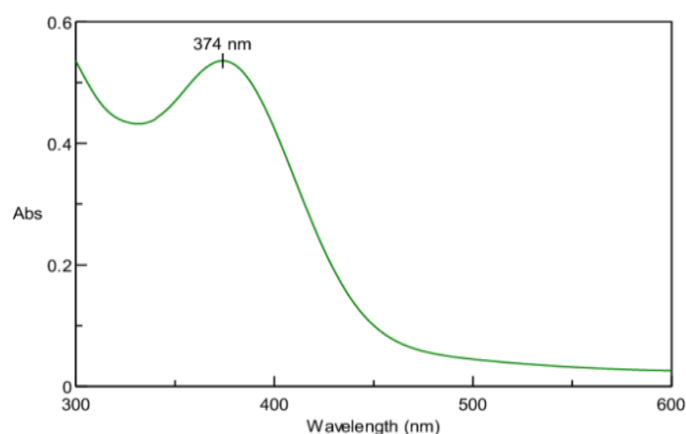


Figure 2. UV-Vis absorption spectrum of ZnO nanoparticles using *Solanum procumbens* leaf extract

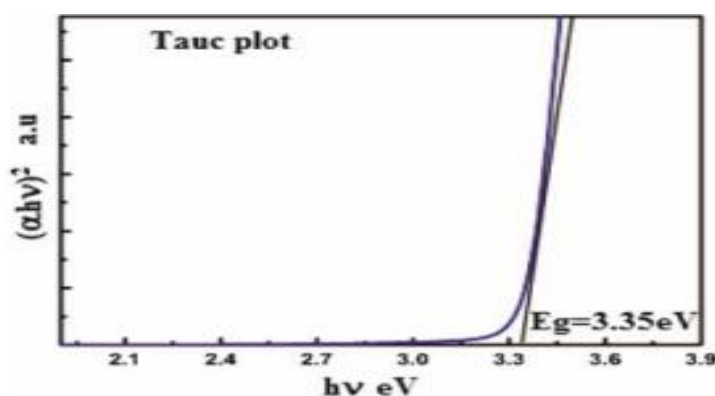


Figure 3. Tauc plots of ZnO nanoparticles using *Solanum procumbens* leaf extract

3.3 FTIR Analysis of ZnO nanoparticles using *Solanum procumbens* leaf extract

FTIR was performed in order to study and determine the functional groups of synthesized ZnO nanoparticles using *Solanum procumbens* leaf extract. Figure 4 shows the FTIR spectrum of synthesized ZnO nanoparticles that were obtained from the green synthesis procedure. FTIR spectrum was observed at 414 cm^{-1} that is attributed to Zn-O stretching vibration. It is a characteristic absorption for ZnO, confirming the presence of zinc oxide in the sample [30]. The peaks at 1339 cm^{-1} and 1556 cm^{-1} are due to symmetric and asymmetric O-C-O stretching vibration of adsorbed carbonate anions respectively. The presence of carbonate suggests that the ZnO nanoparticles may have carbonate groups adsorbed on their surface, which could be a result of the interaction with the leaf extract during the green synthesis process. Meanwhile, the peaks at 1047 cm^{-1} indicate the O-H bending. This peak corresponds to the lattice vibration of carbonate, which further supports the idea of carbonate being present in the synthesized ZnO nanoparticles [31]. The carbonate could also play a role in stabilizing the nanoparticles or influencing their morphology. Overall, the FTIR spectrum confirms the successful synthesis of ZnO NPs and suggests the presence of functional groups from the leaf extract, which may assist in the stabilization and formation of the nanoparticles.

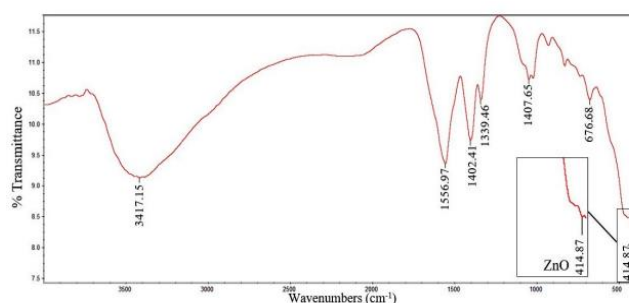


Figure 4. FTIR spectrum of ZnO nanoparticles using *Solanum procumbens* leaf extract

3.4 Anti-inflammatory activity of ZnO nanoparticles using *Solanum procumbens* leaf extract

Anti-inflammatory property was examined using Bovine serum albumin (BSA) denaturation assay. The inhibition of protein denaturation (%) was determined using the following formula: Inhibition of denaturation (%) = $(A_{\text{control}} - A_{\text{sample}}) / A_{\text{control}} \times 100$, where,

A_{control} = Absorbance of the control; A_{sample} = Absorbance of the tested compounds.

The anti-inflammatory activity is exhibited in Fig.5. As the sample concentration increases from $50\text{ }\mu\text{g/mL}$ to $250\text{ }\mu\text{g/mL}$ the inhibition percentage also increases. At the lowest concentration ($50\text{ }\mu\text{g/mL}$), the inhibition is 72.45%, indicating moderate anti-inflammatory activity. The highest concentration tested ($250\text{ }\mu\text{g/mL}$) shows the strongest inhibition at 92.72%, indicating the sample exhibits significant anti-inflammatory effects at higher

concentrations. A high percentage of inhibition indicates that the sample may have strong anti-inflammatory effects, which is applicable for treating inflammatory diseases such as arthritis, allergies, or inflammatory bowel disease. This suggests that the sample might act similarly to anti-inflammatory drugs, either by blocking the production of pro-inflammatory mediators (such as cytokines or prostaglandins) or by interfering with inflammatory cell activity. This effect would be desirable in the development of anti-inflammatory therapies.

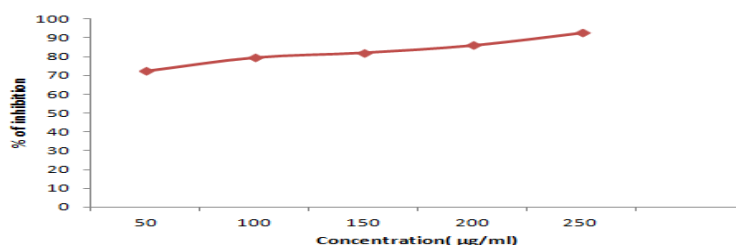


Fig. 5 Anti-inflammatory activity of ZnO nanoparticles using *Solanum procumbens* leaf extract

4. Conclusion

This work introduces a simple, cost-effective, safe and environmentally friendly method for the large-scale synthesis of ZnO nanoparticles using *Solanum procumbens* via a green route. XRD analysis confirmed the crystalline nature of the biosynthesized ZnO nanoparticles. Evidence of ZnO nanoparticle formation was confirmed by a noticeable colour change and a peak around 374 nm in the UV-Vis spectrum. FTIR analysis identified several vibrational functional groups corresponding to the components present in the leaf extract and ZnO nanoparticles. Additionally, the green synthesized ZnO nanoparticles showed significant inflammatory activity, with the percentage of inhibition value of 92.72 µg/mL at 250 concentration. Moreover, the method employed for synthesizing stable ZnO nanoparticles using *Solanum procumbens* offers a safer and more economical alternative to traditional methods, highlighting its potential applications in biomedical research, arthritis, allergic reactions and autoimmune diseases.

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Molecular modelling of Hydroxypropyl Alpha Cyclodextrin inclusion complex with stigmasterol

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ABSTRACT

The geometry and structural features of the inclusion complex of HP α -cyclodextrin (HP α -CD) with the stigmasterol are studied by molecular modeling method. Cyclodextrins are effective host compounds in molecular recognition. To evaluate the complexation role of HP α -CD toward stigmasterol in an attempt to assess their potential as new formulation additives for more efficient drug formulation and delivery is the aim of this study. Cyclodextrin complex was prepared by solvent evaporation method and the formation of inclusion complex was confirmed by NMR spectroscopy. Docking studies generated the most stable complex, demonstrating the aliphatic tail of the guest enters inside the cavity of HP α -CD and the aromatic rings are outside the cavity. The binding energies were essentially due to hydrogen-bonded structures involving the aliphatic chain of the guest. The optimized structures and conformations of HP α -CD and its inclusion compound showed acceptable general agreement with NMR studies. Stoichiometry in the complex formation is 1:1.

Keywords: Hydroxypropyl Cyclodextrin, Stigmasterol, inclusion complex, molecular modelling, NMR spectroscopy

1. Introduction

Cyclodextrins are widely utilized as complexing agents to enhance the solubility of poorly water-soluble drugs, to increase their bioavailability and stability, to prevent gastrointestinal or ocular irritation, to eliminate the unpleasant smells or tastes and to prevent drug-drug or drug-additive interactions [1]. Cyclodextrins present a three-dimensional shape similar to a hollow torus and present different polarities in their interior and exterior surfaces. Their primary and secondary hydroxyl groups are placed on the narrow and the wider rim, respectively. Due to this particular structure, CDs can encapsulate guest molecules leading to the formation of inclusion complexes. Computational chemistry paves the way to understand the mode of interaction between the guest and the host. It also provides the possible orientation of the guest molecule into the cavity of the host molecule. Molecular modelling is a method which predicts the preferred orientation of one molecule to a second when bound to

each other to form a stable complex [2]. Knowledge of the preferred orientation is used to predict the strength of association or binding affinity between two molecules using scoring functions. Hence molecular modelling plays an important role in the rational design of drugs [3]. The aim of molecular modelling is to achieve an optimized confirmation for both the host and the guest, so that the free energy of the overall system is minimized. This research focuses on the inclusion complexation between hydroxypropyl alpha cyclodextrin (HP α -CD) and stigmasterol, lead compound for the formulation of cervical cancer drugs. HP α -CD behaves as host and stigmasterol as guest molecule.

2. Materials and Methods

The molecular modelling of the host-guest interaction was performed as follows: Molecules required (stigmasterol, HP α -CD) for the molecular docking studies were retrieved in the pubchem database and drawn using chem sketch [4]. Before the analysis, molecules were prepared and hydrogen atoms were added by chimera software. Then it was converted as pdb format to molecular docking and inclusion. Initially, the Patchdock server was utilized to process the docking and reveal the grid values (25 \times 25 \times 25). Further, Autodock vina was used to study the host-guest interaction. The grid values were adjusted and executed for molecular docking between stigmasterol and HP α -cyclodextrin. Complex files were analyzed and modeled for major forces by PyMOL and chimera tools. Solid inclusion complex was synthesized by solvent evaporation method [5]. ^1H NMR spectroscopy studies of the solid inclusion complex were recorded in Bruker 400MHz FT-NMR spectrometer. CDCl_3 was used as solvent and Tetramethylsilane (TMS) as internal reference. The chemical shifts (δ) were reported in ppm relative to TMS at 298 K.

3. Results and Discussions

3.1 Molecular Docking Studies

Docking study has been utilized to perform virtual screening of compounds and propose structural hypotheses of how the drug binds with the cyclodextrin for lead optimization. Stigmasterol is docked with HP α -CD after optimizing their structures. The optimized structures of both HP α -CD and stigmasterol are shown in figure 1a and 1b respectively.

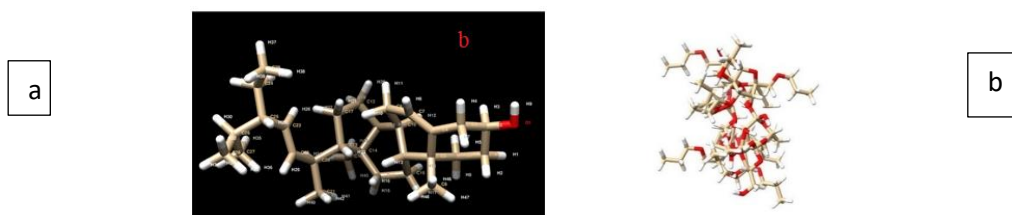


Fig. (1a) Optimised structure of stigmasterol (1b) Optimised structure of HP α -CD

From the figures 1a and 1b it is clear that the aliphatic hydrocarbon tail of stigmasterol has entered through the wider rim of the HP α -CD cavity and the stigmasterol is bound to HP α -CD. The steroid moiety of stigmasterol protrudes on the wider rim of the HP α -CD cavity, which is supported experimentally by NMR studies. Docking studies support the data obtained experimentally. The best binding affinity score of stigmasterol and HP α -CD is -2.36Kcal. Hydrophobic effect is predominant in the HP α -CD inclusion complex, as indicated by green dotted bonds in the figure 2a and 2b. As the spectroscopic data obtained experimentally confirm the formation of inclusion, docking studies also serve as an evidence. Thus, HP α -CD form stable inclusion complex with Stigmasterol.

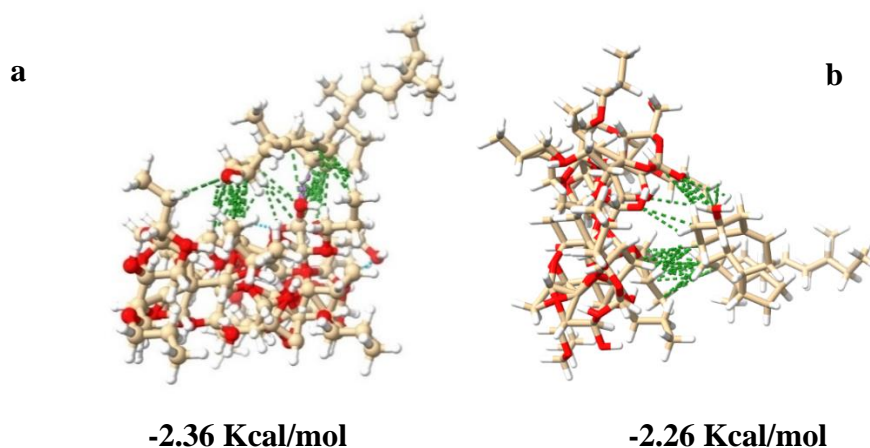


Fig. 2 The most stable optimized geometry of the inclusion complex (stigmasterol: HP α -CD) at different positions

3.2 Nuclear Magnetic Resonance (NMR) Spectroscopic Studies

Chemical shift assignments of ^1H NMR spectrum of stigmasterol, HP α -CD and stigmasterol: HP α -CD is listed in tables. 1. From the chemical shift values, it is clear that in the presence of HP α -CD, aliphatic hydrocarbon tail of stigmasterol undergoes changes in their chemical shift indicating the complex formation between HP α -CD and stigmasterol.

Table 1: Chemical shifts of α -CD and the HP α -CD:S inclusion complex

H	$\delta_{\text{HP } \alpha\text{-CD}}$	$\delta_{\text{HP } \alpha\text{-CD:S}}$	$\Delta\delta$
1	5.360	5.360	0
2	3.80	3.78	-0.02
3	3.35	3.23	-0.13
4	3.97	3.99	0.02
5	3.70	3.61	-0.09
6	5.027	5.027	0

The unaltered ^1H chemical shift due to cyclic hydrocarbons after complex formation demonstrates that cyclic rings are not incorporated into the cavity of HP α -CD. This is because in the cyclodextrin complexes, the mode of binding involves the insertion of the less polar part of the guest into the CD cavity, while the more polar groups remain with the bulk solvent outside [6]. The aliphatic chain would be expected to enter into the cavity due to their hydrophobic nature. Internal protons of HP α -CD are shielded and experience an upfield shift, indicating the presence of electron releasing groups such as the aliphatic end of stigmasterol within the CD cavity. Since the upfield shift of H_3 (-0.13) is greater in magnitude than that of H_5 (-0.09) the inclusion is partial. Thus, NMR spectra serve as good evidence for the formation of an inclusion complex between HP α -CD and stigmasterol.

4. Conclusion

The inclusion complex of stigmasterol with HP α -CD is synthesized by solvent evaporation method. The stoichiometry of the inclusion complexes is determined to be 1:1. Stigmasterol forms a more stable complex with HP α -CD. This may be due to the presence of substituent hydroxypropyl groups in HP α -CD which reduces the interactions of stigmasterol with the aqueous region and enlarges the hydrophobic environment. This enhances the binding of stigmasterol via hydrophobic effect which is confirmed by molecular modelling. The best binding affinity score of stigmasterol and HP α -CD is -2.36 Kcal. The preferred orientation is energetically favorable. ^1H -NMR studies serve as supporting evidence for the formation of an inclusion complex. The formation of strong inclusion could increase solubility and hence, facilitate the delivery of stigmasterol preventing the undesired properties of stigmasterol.

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Green Synthesis of Silver Nanoparticles Using *Sansevieria zeylanica* Leaf Extract

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ABSTRACT

Interest in the biosynthesis of nanoparticles has significantly increased due to their potential applications in medicine, environmental science, and technology. This study demonstrates an economical, sustainable, and a green synthesis approach for silver nanoparticles (AgNPs) utilizing leaf extract of Sansevieria zeylanica. The biosynthetic process is rapid and straightforward, monitored through visual color changes and ultraviolet-visible (UV-Vis) spectroscopy. The synthesized AgNPs were characterized using X-ray diffraction (XRD), Fourier-transform infrared spectroscopy (FTIR), and scanning electron microscopy (SEM). UV-Vis spectra revealed specific Surface Plasmon Resonance (SPR) absorption peaks at 555 nm, confirming the formation of AgNPs. XRD analysis indicated the crystalline structure of AgNPs, while FTIR spectra showed interactions between plant bioactive compounds and the nanoparticles. SEM analysis revealed spherical nanoparticles with uniform morphology. Phytochemical screening of Sansevieria zeylanica leaf extract indicated the presence of alkaloids, flavonoids, tannins, proteins, saponins, carbohydrates, and phenols, which facilitated the capping and stabilization of AgNPs.

Keywords: Silver nanoparticles; Biosynthesis; *Sansevieria zeylanica* extract

1. Introduction

In recent years, biological methods for nanoparticle synthesis have attracted considerable interest due to their advantages [1]. Utilizing plant extracts as natural reducing and stabilizing agents for nanoparticle synthesis has emerged as a promising approach [2]. *Sansevieria zeylanica*, commonly known as snake plant or mother-in-law's tongue, is a perennial herbaceous plant with medicinal properties, hardiness and air-purifying properties Somashekara [3]. The phytochemical composition of *Sansevieria zeylanica* includes various secondary metabolites such as flavonoids, phenolics, and alkaloids, which possess reducing and stabilizing properties [4]. This makes *Sansevieria zeylanica* an attractive candidate for the green synthesis of nanoparticles. Have gained considerable attention due to their distinctive physicochemical characteristics, such as a high surface area-to-volume ratio, excellent antimicrobial activity and catalytic properties [5].

The fabrication of silver nanoparticles through synthesis using plant extracts offers advantages such as cost-effectiveness, scalability, and biocompatibility [6]. Additionally, Using reducing agents removes the necessity for the need for harsh chemicals, making the process environmentally benign [7]. This study aims to explore the potential of *Sansevieria zeylanica* plant extract for the synthesis of silver nanoparticles. The green synthesis approach offers a sustainable and environmentally friendly alternative to conventional chemical methods [8]. Characterization techniques like UV-Vis spectroscopy, Fourier-transform infrared spectroscopy (FTIR), scanning electron microscopy (SEM), and X-ray diffraction (XRD) will be utilized to examine the size, morphology, and crystalline structure of the synthesized silver nanoparticles. Furthermore, the catalytic activities of the nanoparticles will be evaluated, highlighting their potential application in biomedical, environmental, and industrial sectors[9]. Overall, the utilization of *Sansevieria zeylanica* plant extract for the green synthesis of silver nanoparticles presents an opportunity to harness the inherent reducing and stabilizing properties of phytochemicals, contributing to the development of sustainable nanotechnology with diverse practical applications [10].

2. Materials and Methods

2.1 Plant Materials and Extract Preparation

Fresh leaves of *Sansevieria zeylanica* were collected, washed thoroughly with distilled water, and air-dried at room temperature. The dried leaves were ground into a fine powder and subjected to solvent extraction using a Soxhlet apparatus with ethanol. The extract was filtered and stored at 4°C for further use.



Fig. 1. Leaf of *Sansevieria zeylanica* used for the synthesis

2.2 Synthesis of Silver Nanoparticles

To synthesize AgNPs, a specific volume of *Sansevieria zeylanica* extract was mixed with an aqueous solution of silver nitrate (AgNO_3) in a glass beaker. The reaction mixture was stirred continuously at room temperature. The reduction of silver ions was visually confirmed by a color change from pale yellow to brown, indicating the formation of AgNPs.

3. Results and Discussion

3.1 Phytochemical Analysis

Phytochemical screening of *Sansevieria zeylanica* leaf extract revealed the existence of secondary metabolites, including alkaloids and flavonoids, tannins, proteins, saponins, carbohydrates, and phenols. These bioactive compounds facilitated the reduction of Ag^+ ions and stabilized the synthesized AgNPs.



Fig. 2 Photographs of (A) Alkaloids, (B) Flavonoids, (C) Tannins, (D) Proteins, (E) Saponins, (F) Carbohydrates, (G) Phenols.

3.2 UV-Vis Spectroscopy

The UV-Vis spectra of the synthesized AgNPs exhibited a characteristic SPR peak at 555 nm, confirming the formation of silver nanoparticles. The brown coloration of the reaction mixture further indicated successful synthesis.

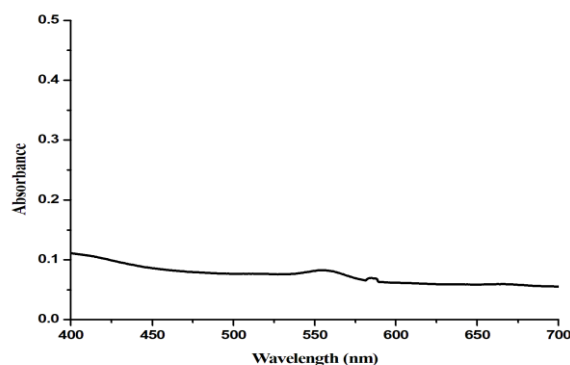


Fig. 3. UV-Vis Spectrum of *S. zeylanica* AgNPs

3.3 FTIR Analysis

FTIR spectra of the synthesized AgNPs revealed functional groups such as hydroxyl and carbonyl, which contributed to the capping and stabilization of nanoparticles. The presence of these groups confirmed interactions between the bioactive compounds of *Sansevieria zeylanica* and the AgNPs.

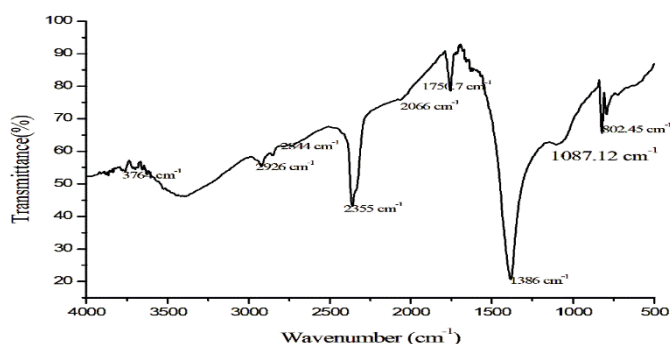


Fig. 4. FTIR spectra of *Sansevieria zeylanica* extract

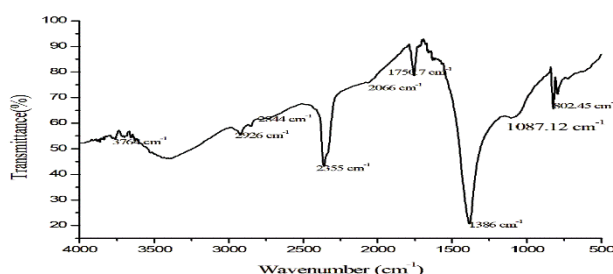


Fig. 5. FTIR spectra of AgNPs synthesized from *Sansevieria zeylanica* extract

3.4 X-ray Diffraction Analysis

XRD analysis showed distinct peaks corresponding to the face-centered cubic (fcc) structure of silver. The average size of the synthesized AgNPs was calculated to be approximately 76.7 nm using Debye-Scherrer's equation.

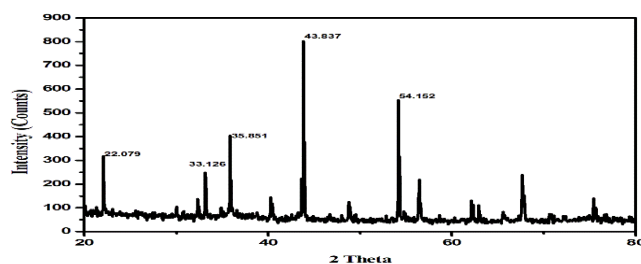


Fig. 6. XRD Spectrum of *S. zeylanica* AgNPs

3.5 SEM Analysis

The synthesized AgNPs were predominantly spherical with a uniform surface, as evidenced by SEM images. The UV-Vis and XRD results were consistent with the uniform morphology and size distribution.

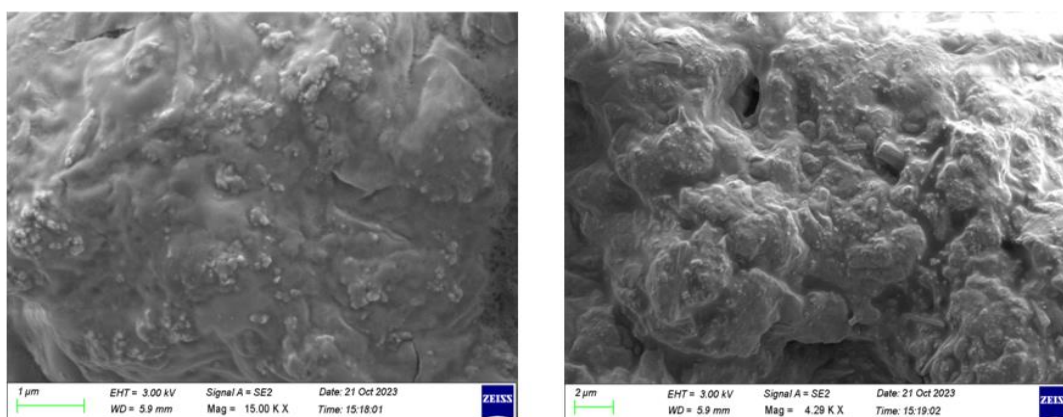


Fig. 7. SEM images of synthesized *Sansevieria zeylanica* based silver nanoparticles

3.6 EDX Studies

The EDAX spectral image displayed the presence of metallic silver at 3KeV. The weight percentage of silver (Ag) and Oxygen (O) in AgNPs are 47.81 and 30.34 respectively.

The other elements found in the spectrum indicate the organic components found in the extract present in the surface of the silver nanoparticles.

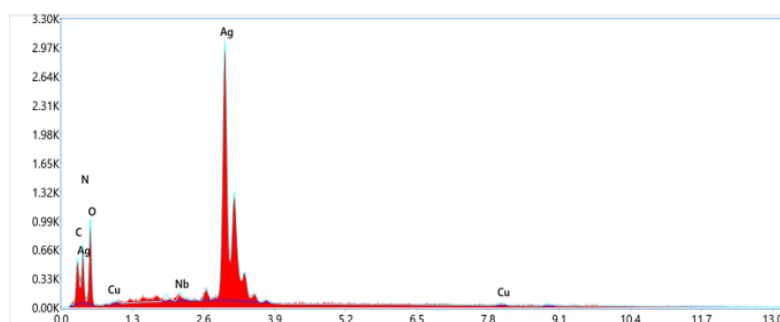


Fig. 8. EDAX Spectrum of AgNPs synthesized from ethanolic leaf extract of *Sansevieria zeylanica*

4. Conclusion

Fast biological production of silver nanoparticles utilizing *Sansevieria zeylanica* ethanolic leaf extract provides an environmental friendly, simple, and efficient route for synthesis of benign nanoparticles. A simple one-pot eco-friendly fabrication of stable silver nanoparticles using *Sansevieria zeylanica* leaf extract at room temperature was reported in this study. The produced silver nanoparticles were analyzed for characterization such as UV, FR-IR, XRD, and SEM. Phytochemical screening of ethanolic leaf extract of *Sansevieria zeylanica* confirmed the presence of Alkaloids, Flavonoids, Tannins, Proteins, Saponins,

Carbohydrates and Phenols. The formation of AgNPs was confirmed through Surface Plasmon Resonance around 555 nm for ethanolic leaf extract. The FTIR spectra are useful in studying the biomolecules responsible for reducing silver nitrate solution to silver nanoparticles in ethanolic leaf extract. XRD study showed the particle size around 7 nm. FESEM studies revealed spherical shaped silver nanoparticles. Hence the presence of phytoconstituents is crucial. to use nanoparticles in the medicinal field.

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Ethnobotanical Survey of Medicinal Plants Used by Traditional Healers in Arugankulam Village of Tirunelveli District, Tamil Nadu

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ABSTRACT

Plants have long been utilized for treating various ailments, with the people of Arugankulam Village in Tamil Nadu relying on medicinal plants for their healthcare needs. Many community members possess a basic understanding of local plants used for first aid remedies, including treatments for conditions such as colds, coughs, fever, headaches, poisonous bites, and other common ailments. The aim of this study was to identify traditional healers practicing herbal medicine in Arugankulam Village, Tamil Nadu, and to document their indigenous knowledge regarding the use of medicinal plants, with a particular focus on the most commonly used ethnomedicinal species. The field study was conducted over eight months, during which ethnomedicinal information was gathered through interviews with local healers. A total of 105 plant species, representing 86 genera and 44 families, were identified as commonly used by traditional healers for treating 125 different ailments. Leaves were the most frequently used plant part. This study emphasizes the valuable ethnobotanical knowledge in Arugankulam Village and its potential for developing herbal-based drugs and products. A list of medicinal plants and their uses, as practiced by the people of the Arugankulam village, is provided in this paper.

Keywords: Ethnobotany, medicinal plants, traditional knowledge, Arugankulam Village, Tirunelveli district.

1. Introduction

Ethnobotany, which explores the connections between human societies and plant life, is crucial for understanding both traditional medicinal practices and the cultural importance of various plant species. In Arugankulam Village, situated in Tamil Nadu's Tirunelveli District, India, traditional healers harness a diverse array of local plants to treat a range of health conditions, building on generations of indigenous wisdom [1]. Traditional medicine holds great importance globally, with a significant portion of the population depending on

herbal treatments to meet healthcare needs. In rural areas such as Arugankulam, where access to modern medical services may be restricted, communities often rely on traditional healers. These healers have a deep knowledge of local plants, often inherited across generations, allowing them to address health issues from minor illnesses to chronic conditions [2].

The Tirunelveli District, known for its ecological diversity and rich biodiversity, provides an ideal setting for conducting an ethnobotanical study. The region's varied climate and geography support a wide array of medicinal plants. Yet, with the rise of modernization and a reduction in traditional practices, there is an increasing risk that this invaluable knowledge may be lost [3]. The therapeutic properties of these plants also merit scientific investigation. Numerous plants used in traditional medicine are known to contain bioactive compounds with significant pharmacological potential, underscoring the value of ethnobotanical research for contemporary medicine [4].

The relationship between cultural practices and medicine deepens our insight into health and wellness within diverse communities, positioning this research as a meaningful addition to ethnobotanical knowledge [5]. This ethnobotanical study in Arugankulam Village is designed not only to catalogue the medicinal plants and the practices employed by traditional healers but also to underscore the necessity of preserving indigenous knowledge [6]. By bridging traditional and contemporary medical practices, the research aims to enhance appreciation for the role of plants in healthcare and the deep-seated wisdom within local communities. Ultimately, this investigation highlights the enduring bond between humans and nature, demonstrating how traditional practices can inform and improve modern health paradigms [7]. This study aims to document and analyze the medicinal plants utilized by traditional healers in Arugankulam, contributing to the preservation of local biodiversity and traditional knowledge systems while providing a foundation for future research on potential novel therapeutic agents.

2. Materials and Methods

Arugankulam Village in Tirunelveli District, Tamil Nadu, is renowned for its biodiversity and traditional herbal medicine practices. This study involved 13 exploratory visits to document medicinal plants used by local healers, guided by semi-structured interviews and field observations. Thirty traditional healers were selected through community consultations, and their knowledge on plant usage, preparation, and therapeutic applications was meticulously recorded. Medicinal plants were identified in their natural habitats, focusing on key morphological traits, with taxonomic verification through herbarium specimens and expert consultations. References such as Flora of the Presidency of Madras

and Flora of Tirunelveli Hills supported accurate classification. Ethno botanical interviews, conducted with consent, were analyzed qualitatively to categorize plant use and cultural significance. Preserved specimens are housed at St. John's College, Palayamkottai [8].

3. Results and Discussion

Sl. No	Botanical Name	Family	Habit	Useful Parts	Medicinal Uses
1	<i>Abutilon indicum</i> (L). Sw.	Malvaceae	Shrub	Leaves, Roots	Respiratory Disorders, Wound Healing, Management of Urinary Issues, Pain Relief, Antiseptic, diuretic, Digestive Aid, Anti-inflammatory.
2	<i>Acalypha indica</i> L.	Euphorbiaceae	Herb	Leaves	Treatment of Respiratory Issues, Skin Disorders, Expectorant, laxative, Pain Relief Support for Digestive Health.
3	<i>Achyranthes aspera</i> L.	Amaranthaceae	Herb	Roots and Seeds	Wound Healing and Skin Care Disorders, Pain and Inflammation Relief, Diuretic.
4	<i>Adhatoda vasica</i> Nees.	Acanthaceae	Shrub	Leaves	Management of Tuberculosis, Control of Bleeding Disorders, Expectorant, Antitussive, Bronchodilator, Digestive Health.
5	<i>Aegle marmelos</i> (L.) Correa.	Rutaceae	Tree	Fruits and Leaves	Antioxidant, Antidiarrheal, Management of Diabetes, Treatment of Gastrointestinal Disorders, Immune System Support.
6	<i>Aloe vera</i> (L.) Burm.f.	Liliaceae	Herb	Leaves	Antiseptic, Skin coolant, Moisturizing, Antidiabetic, Hair Care.
7	<i>Alternanthera sessilis</i> (L.) R.Br. ex Dc.	Amaranthaceae	Herb	Leaves and stems	Antipyretic, Diuretic, Eye Infections. Wound Healing, Respiratory Disorders, Anti-inflammatory and Fever Relief.
8	<i>Amaranthus spinosus</i> L.	Amaranthaceae	Herb	Roots and Leaves	Diuretic, Anti-inflammatory. Skin Conditions,

					Gastrointestinal Disorders, Blood Purification, Support for Urinary Health, Fever and Respiratory Relief.
9	<i>Andrographis echinoides</i> (L.) Nees.	Acanthaceae	Herb	Whole plant	Treatment of Skin Disorders Management of Fever, Antimicrobial, Anti-inflammatory, Support for Gastrointestinal Health, and Respiratory Health.
10	<i>Andrographis alata</i> (Vahl.) Nees.	Acanthaceae	Under shrub	Whole plant	Anti-inflammatory, Relief for Respiratory Ailments, Gastrointestinal Support.
11	<i>Andrographis paniculata</i> (Burm.f) Wallich. Nees.	Acanthaceae	Herb	Leaves and stem	Boosting Immune System, Digestive Health, Liver Protection and Detoxification, Treatment of Respiratory Disorders.
12	<i>Annona squamosa</i> L.	Annonaceae	Tree	Leaves, Fruits and seeds	Treatment of Digestive Disorders, Pain Relief, Deworming, skin care, Management of Fever and Inflammation.
13	<i>Argemone mexicana</i> L.	Papaveraceae	Herb	Seeds and Latex	Anthelmintic, Analgesic. Antimalarial.
14	<i>Aristolochia bracteolata</i> Lam.	Aristolochiaceae	Herb	Leaves and roots	Anti-inflammatory, Digestive aid, Management of Fever and Malaria, Support for Reproductive Health.
15	<i>Asystasia gangetica</i> (L.) T. Anderson	Acanthaceae	Creepers	Leaves	Antioxidant, Anti-inflammatory, Treatment of Snake Bites, Management of Respiratory Issues.
16	<i>Azadirachta indica</i> A. Juss.	Meliaceae	Tree	Leaves and bark	Antiseptic, Antimicrobial, Treatment of Skin Disorders, Dental and Oral Health, Pest Control and Antiparasitic Use, Blood Purification and Detoxification.
17	<i>Boerhavia diffusa</i> L.	Nyctaginaceae	Herb	Roots and Leaves	Kidney and Urinary Disorders, Liver Health, Management of Diabetes, Respiratory Disorders.
18	<i>Calotropis gigantea</i> (L.)	Asclepiadaceae	Shrub	Leaves and roots	Analgesic, Anti-inflammatory.

	R.Br.				
19	<i>Calotropis procera</i> (L.) R.Br	Asclepiadaceae	Shrub	Latex leaves	Analgesic, Stimulant, Anthelmintic and Purgative.
20	<i>Capsicum annum</i> L.	Solanaceae	Herb	Fruit	Antiseptic, Anti-inflammatory, Weight Management, Boosting Immunity.
21	<i>Cardiospermum halicacabum</i> L.	Sapindaceae	Herb	Leaves	Anti-inflammatory. Pain Relief, Anti-rheumatic, Antioxidant and General Health Tonic
22	<i>Carica papaya</i> L.	Caricaceae	Tree	Leaves and fruit	Anthelmintic, Digestive aid. Anti-inflammatory and Pain Relief, Wound Healing and Skin Care, Anti-parasitic, Boosting Immune System.
23	<i>Cassia auriculata</i> L.	Caesalpiniaceae	Shrub	Flowers and leaves	Antidiabetic, Liver Health and Detoxification, Skin Health and Hair care, Antibacterial and Antifungal.
24	<i>Cassia mimosoides</i> L.	Caesalpiniaceae	Shrub	Leaves and pods	Laxative, Digestive Aid, Antimicrobial, Fever and Antipyretic.
25	<i>Cassia senna</i> L.	Caesalpiniaceae	Shrub	Leaves and pods	Laxative, purgative, Detoxification and Liver Health, Skin Care, Weight Loss.
26	<i>Catharanthus roseus</i> L.	Apocynaceae	Shrub	Leaves and roots	Anticancer, Antidiabetic, Diabetes Management, Blood Pressure Reduction.
27	<i>Centella asiatica</i> (L.) Urb.	Apiaceae	Creeping Herb	Leaves	Wound healing, Cognitive enhancer, Memory Enhancement, Stress Reduction, Circulatory Health and Varicose Veins, calming effects on the nervous system.
28	<i>Centrosema pubescens</i> Benth.	Fabaceae	Climber	Leaves and Roots	Analgesic, Febrifuge, Anthelmintic, Antioxidant, Health Tonic, Diuretic, Respiratory Health.
29	<i>Chromolaena odorata</i> (L.) R. King.	Asteraceae	Shrub	Leaves	Hemostatic, Wound healing, Antimalarial, Coughs, Colds, and

					Respiratory Conditions.
30	<i>Cissus quadrangularis</i> L.	Vitaceae	Herb	Stems	Anti-inflammatory. Bone Health and Fracture Healing Weight Loss, Digestive Health, Antioxidant.
31	<i>Citrullus colocynthis</i> L.	Cucurbitaceae	Climber	Fruits and roots	Laxative, Anthelmintic, Detoxification and Liver Health.
32	<i>Clitoria ternatea</i> L.	Fabaceae	Climber	Flowers and roots	Cognitive enhancer, anxiolytic, brain tonic.
33	<i>Coccinia grandis</i> (L.) Voigt.	Cucurbitaceae	Herbaceous vine	Leaves and fruit	Antidiabetic, antioxidant, Anti-stress, Antimicrobial, Weight Loss, Immune Booster.
34	<i>Cocos nucifera</i> L.	Arecaceae	Tree	Fruits	Antioxidant, Skin moisturizer.
35	<i>Coleus aromaticus</i> Benth.	Lamiaceae	Herb	Leaves	Expectorant, Digestive aid, Respiratory Health, Stomach Disorders.
36	<i>Colocasia sculenta</i> (L.) Schott	Araceae	Herb	Corms and leaves	Nutritive, Digestive Health demulcent. Skin Care and Wound Healing, Remedy for Respiratory Issues.
37	<i>Crotalaria retusa</i> L.	Fabaceae	Shrub	Leaves and seeds	Anti-inflammatory, Antimicrobial, Anthelmintic, Cough and Respiratory Health.
38	<i>Crotalaria verrucosa</i> L.	Fabaceae	Shrub	Leaves and roots	Antiseptic, Anti-inflammatory, Antioxidant and Hepatoprotective.
39	<i>Cucumis sativus</i> L.	Cucurbitaceae	Climber	Fruit	Coolant, Anti-inflammatory, Skin Care and Soothing, Digestive Health, Weight Loss.
40	<i>Curcuma longa</i> L.	Zingiberaceae	Herb	Rhizome	Antiseptic, Anti-inflammatory, Pain Relief, Liver Protection, Neuroprotective Effects.
41	<i>Cyperus rotundus</i> L.	Poaceae	Herb	Rhizome	Digestive aid, Anti-inflammatory, Menstrual Disorders, Respiratory Health.
42	<i>Cymbopogon citratus</i> (DC.) Stapf.	Poaceae	Herb	Leaves	Antibacterial, Digestive aid. Stress Relief, Anxiety Reduction, Detoxification and Antioxidant

43	<i>Cynodon dactylon</i> (L.) Pers.	Poaceae	Herb	Whole plant	Hemostatic, Anti-Inflammatory, Urinary Health, Wound Healing and Skin Care.
44	<i>Euphorbia heterophylla</i> L.	Euphorbiaceae	Herb	Leaves and Latex	Antimicrobial, Laxative, Treatment of Warts and Tumors.
45	<i>Euphorbia hirta</i> L.	Euphorbiaceae	Herb	Whole plant	Antiasthmatic, antimicrobial, Diuretic and Kidney Health.
46	<i>Evolvulus alsinoides</i> (L.) L.	Convolvulaceae	Herb	Whole plant	Cognitive enhancer, anxiolytic, Memory Booster, Stress Relief, Improving Sleep.
47	<i>Ficus benghalensis</i> L.	Moraceae	Tree	Bark and aerial roots	Astringent, antidiabetic, Skin Care, Anti-inflammatory and Pain Relief.
48	<i>Ficus religiosa</i> L.	Moraceae	Tree	Leaves and bark	Antiseptic, Wound healing, Pain Relief, Blood Sugar Regulation and Anti-diabetic Effects.
49	<i>Hibiscus lobatus</i> (Murray) Kuntze	Malvaceae	Herb	Leaves and flowers	Antipyretic, digestive aid, skin Health and Wound Healing.
50	<i>Hibiscus rosa-sinensis</i> L.	Malvaceae	Shrub	Flowers and Leaves	Antioxidant, Hair Care and Scalp Health, Skin Health, Anti-aging Effects, Digestive Health, Heart health and Detoxification.
51	<i>Hedyotisum bellate</i> L.	Rubiaceae	Herb	Whole plant	Anti-Inflammatory, antimicrobial, Anti-diabetic, Immunomodulatory Effects, Liver Health and Detoxification.
52	<i>Hygrophila auriculata</i> (Schumach).	Acanthaceae	Herb	Roots and seeds	Diuretic, Anti-Inflammatory, Treatment of Skin Disorders and Wound Healing.
53	<i>Indigo feratinctoria</i> L.	Fabaceae	Shrub	Leaves	Antiseptic, Anti-Inflammatory, Dyeing and Textile Industry.
54	<i>Ipomoea aquatic</i> Forsskal.	Convolvulaceae	Herb	Leaves and stems	Laxative, Anti-Inflammatory. Blood Pressure Regulation, Skin Health.
55	<i>Ipomoea indica</i> L.	Convolvulaceae	Herb	Leaves and roots	Antibacterial, Digestive aid, Respiratory Health and Cough Relief,

					Wound Healing and Improving Sleep
56	<i>Ixora coccinea</i> L.	Rubiaceae	Shrub	Flowers and roots	Antioxidant, astringent, Diabetic Management, Digestive Health.
57	<i>Jasminum angustifolium</i> (L) Willd.	Oleaceae	Shrub	Leaves and flowers	Aromatic, Anti-Inflammatory, Sedative, Anxiety Relief, Skin Health, Wound Healing, Respiratory Health.
58	<i>Jatropha curcas</i> L.	Euphorbiaceae	Small tree	Seeds and leaves	Antimicrobial, purgative, Wound Healing and Skin Disorders.
59	<i>Justiciapro cumbens</i> L.	Acanthaceae	Herb	Whole plant	Anti- Inflammatory, Antipyretic, Skin Health, Antioxidant and Detoxification.
60	<i>Lablab purpureus</i> (L.) Sweet.	Fabaceae	Herb	Seeds and leaves	Antidiabetic, antioxidant, Blood Pressure Regulation.
61	<i>Lantana camera</i> L.	Verbenaceae	Shrub	Leaves and flowers	Antimicrobial, antipyretic, Digestive Health.
62	<i>Lawsonia inermis</i> L.	Lythraceae	Shrub	Leaves	Antiseptic, coolant, Hair and Skin Dye.
63	<i>Leucas aspera</i> (Willd.) Link.	Lamiaceae	Herb	Leaves and flowers	Antipyretic, antimicrobial, Wound Healing.
64	<i>Mangifera indica</i> L.	Anacardiaceae	Tree	Leaves, bark and fruits	Antioxidant, digestive aid, Blood Sugar Regulation.
65	<i>Mimosa pudica</i> L.	Fabaceae	Herb	Leaves and roots	Antiseptic, wound healing, Nervous System and Stress Relief.
66	<i>Mirabilis jalapa</i> L.	Nyctaginaceae	Herb	Leaves and roots	Antiviral, Anti-Inflammatory, Antioxidant.
67	<i>Morinda tinctoria</i> Roxb.	Rubiaceae	Small tree	Roots and fruit	Antimicrobial, Dyeing and Textile Industry, hepatoprotective, Blood Purification and Detoxification.
68	<i>Murraya koenigii</i> (L.) spreng	Rutaceae	Small tree	Leaves	Anti-diabetic, antioxidant, Hair Care, Blood Sugar Regulation.
69	<i>Musa paradisiaca</i> L.	Musaceae	Herb	Fruits and flowers	Astringent, digestive aid, Blood Pressure Regulation, Wound Healing, Skin Health.

70	<i>Nerium oleander</i> L.	Apocynaceae	Shrub	Leaves	Cardiotonic, Anti-cancer, Anti-Inflammatory, Antiviral Effects.
71	<i>Ocimum sanctum</i> L.	Lamiaceae	Herb	Leaves	Antiseptic, Stress Relief, Immunomodulatory, Immune System Boost, Blood Sugar Regulation.
72	<i>Ocimum tenuiflorum</i> L.	Lamiaceae	Herb	Leaves	Antioxidant, adaptogenic, Blood Sugar Regulation, Stress Relief, Immune System Support, Skin and Liver Health.
73	<i>Opuntia stricta</i> (Haw.) Haw. var. <i>dilleni</i> (Ker Gawl.) L.D. Benson.	Cactaceae	Shrub	Pods and fruits	Antioxidant, Anti-Inflammatory, Nutritional Value and Edible Fruit, Diabetes Management.
74	<i>Oryza sativa</i> L.	Poaceae	Herb	Grain and bran	Culinary Uses, Staple Food, Demulcent, nutritive. Diarrhea, Skin Care, Cosmetic Uses, Blood Sugar Regulation, Rice Bran Oil and Health Benefits.
75	<i>Passiflora edulis</i> Sims	Passifloraceae	Herb	Leaves and fruits	Culinary Uses, Sedative and Anxiety Relief, Antioxidant and Immune Boosting anti-tumor, antidiabetic, Heart Health.
76	<i>Passiflora foetida</i> L.	Passifloraceae	Herb	Leaves and fruits	Sedative, antispasmodic, Anxiety Relief, Immune Support, Fertility and Reproductive Health.
77	<i>Phyllanthus amarus</i> Schum & Thonner	Phyllanthaceae	Herb	Whole plant	Kidney Stone Treatment, Liver Health and Hepatoprotective, antiviral, Blood Sugar Regulation.
78	<i>Phyllanthus acidus</i> L.	Phyllanthaceae	Tree	Fruit	Diuretic, Antioxidant and Immune Support, Liver Health and Detoxification
79	<i>Phyllanthus emblica</i> L.	Phyllanthaceae	Tree	Fruit	Rich Source of Vitamin C and Immunity, Anti-aging and Skin Health Booster, Liver Protection, Cardiovascular Health, Blood Sugar Regulation, Antioxidant, Immunomodulatory.

80	<i>Polyalthia longifolia</i> (Sonn). Thwaites	Annonaceae	Tree	Bark and leaves	Antibacterial, Febrifuge, Mental Health and Stress Relief, Antioxidant and Anti-aging Effects.
81	<i>Pongamia pinnata</i> L. Pierre.	Fabaceae	Tree	Seeds	Antimicrobial, Anti-Inflammatory, Liver Protection and Detoxification, Blood Sugar Regulation, Insect Repellent.
82	<i>Portulaca quadrifida</i> L.	Portulacaceae	Herb	Leaves and stems	Diuretic, coolant, Blood Sugar Regulation, Biofuel Production.
83	<i>Psidium guajava</i> L.	Myrtaceae	Tree	Leaves and fruit	Antidiarrheal, antimicrobial, Cough and Cold Relief, Liver Health, Weight Loss, Anticancer
84	<i>Punica granatum</i> L.	Lythraceae	Tree	Fruits and bark	Antioxidant, antimicrobial, Cardiovascular Health, Anticancer, Weight Loss, Hair Care.
85	<i>Ricinus communis</i> L.	Euphorbiaceae	Shrub	Seeds	Laxative, Digestive Aid, Skin and Hair Care, Anti-Inflammatory. Reproductive Health.
86	<i>Setaria pumila</i> (J. Koenig) Stapf.	Poaceae	Herb	Seeds	Diuretic, Nutritive, Food Source, urinary disorders and digestive issues.
87	<i>Sida cordata</i> (Burm.f) Borssum.	Malvaceae	Herb	Leaves and roots	Anti- Inflammatory, Antipyretic, Respiratory Disorders, Immunity Booster.
88	<i>Sida rhombifolia</i> L.	Malvaceae	Herb	Roots and Leaves	Anti- Inflammatory, analgesic, Fever and General Health Tonic, Stress Relief.
89	<i>Solanum nigrum</i> L.	Solanaceae	Herb	Leaves and Berries	Anti- Inflammatory, antipyretic, Stress Relief, Veterinary Medicine.
90	<i>Solanum procumbens</i> Lour.	Solanaceae	Herb	Whole plant	Anti- Inflammatory, antispasmodic.
91	<i>Solanum trilobatum</i> L.	Solanaceae	Climbin g herb	Leaves and Berries	Expectorant, Antiasthmatic, Treatment of Respiratory Disorders, General Health Tonic and Fever Management.

92	<i>Solanum virginianum</i> L.	Solanaceae	Shrub	Roots and fruits	Expectorant, Antiasthmatic, Urinary Disorders. Snakebite Remedies.
93	<i>Tamarindus indica</i> L.	Fabaceae	Tree	Fruit pulp and leaves	Laxative, antioxidant, Treatment of Fevers and Malaria, Cooling Agent, Oral health.
94	<i>Tecoma stans</i> (L.) Kunth.	Bignoniaceae	Shrub	Leaves and flowers	Antidiabetic, Diuretic, Treatment of Fever and Malaria, Diuretic and Detoxifying Agent.
95	<i>Tectona grandis</i> L.f.	Lamiaceae	Tree	Leaves and bark	Anti- Inflammatory, Antibacterial, Treatment of Fever and Malaria, Cardiovascular Health.
96	<i>Terminalia catappa</i> L.	Combretaceae	Tree	Leaves and fruit	Antioxidant, Cardiovascular Health, Hepatoprotective.
97	<i>Thespesia populnea</i> (L.) Sol. Ex. Correa	Malvaceae	Tree	Bark and leaves	Antidiabetic and Blood Sugar Regulation, Anti-Inflammatory, Wound healing.
98	<i>Tinospora cordifolia</i> (Willd.) Miers ex Hook. f. & Thomson.	Menispermaceae	Climbing Herb	Stem	Immunomodulatory, antipyretic, Reproductive Health, Fever Reduction.
99	<i>Tribulus terrestris</i> L.	Zygophyllaceae	Herb	Fruits and roots	Diuretic, aphrodisiac, Enhancing Reproductive Health and Fertility, Boosting Energy and Physical Stamina.
100	<i>Tridax procumbens</i> L.	Asteraceae	Herb	Leaves	Antiseptic, Control of Hair Loss and Dandruff, Hemostatic, Wound healing.
101	<i>Vernonia cinerea</i> (L.) Less.	Asteraceae	Herb	Whole plant	Anti- Inflammatory, Antipyretic, Digestive Health and Appetite Stimulation, Smoking Cessation Aid.
102	<i>Vitex negundo</i> L.	Lamiaceae	Shrub	Leaves and roots	Anti- Inflammatory, analgesic, Relief from Pain.
103	<i>Wattakaka volubilis</i> (L.f.) T. Cooke	Apocynaceae	Climbing shrub	Leaves and roots	Anti- Inflammatory, antipyretic, Menstrual and Reproductive Health.

104	<i>Zingiber officinale</i> Rosc.	Zingiberaceae	Herb	Rhizome	Immune Boosting, Cold Remedies, Anti-Inflammatory, Digestive aid, Stress Relief, Liver Detoxification.
105	<i>Ziziphus mauritiana</i> Lam.	Rhamnaceae	Small tree	Fruits and leaves	Antioxidant, antimicrobial, Fever and Inflammation Reduction, Immune Booster and General Tonic.

This study highlights the traditional medicinal knowledge of Arugankulam village, documenting 105 plant species belonging to 86 genera and 44 families (Table 1). The Fabaceae family had the highest representation with 8 species, followed by Acanthaceae (7 species), and Malvaceae and Lamiaceae (6 species each). Herbaceous plants constituted 49% of the recorded species, reflecting their accessibility and efficacy in traditional medicine, as similarly observed among the Kani tribe in Karayar tribal village. Ethno botanical investigations by researchers such as [9, 10] also emphasize the significance of documenting traditional plant knowledge across different regions of India. Leaves were the most frequently used plant part (70%), a preference that aligns with other studies, as leaves are easy to harvest without harming the plant, available throughout the year, and rich in bioactive compounds vital for plant metabolism. Other plant parts used included fruits and roots (20%), flowers (7%), and bark, seeds, and bulbs (3%). A related ethnobotanical survey conducted by Sugumaran *et al.* [11] in the Pechiparai Hills documented 138 medicinal plant species used by the Kani tribes, with the Leguminosae family being most prominent (19 species, 14%). Leaves were again the primary plant part utilized (50%, 69 species), with leaf extracts commonly prepared as juice (26%) and administered orally (53%).

Similar findings by a total of 540 species were identified as herbs, predominantly annuals, along with 100 shrub species, 200 tree species, and 160 climbers. Additionally, 20 species of ferns and conifers and 15 orchid species were recorded. These plants were documented as Indian medicinal species through field studies conducted among 1,000 wild plants [12]. Similar research was conducted by Ragupathy and Newmaster [20] which explored the Irulas community's use of medicinal flora in the Kodyakarai Reserve Forest. The study identified Euphorbiaceae (4 species) and Fabaceae (9 species) as the most commonly represented plant families. The documented flora included 10 herb species, 13 shrub species, and several climbers, emphasizing the region's biodiversity and its significance in traditional medicine [13]. Elumalai *et al.* [14] assessed ethnobotanical survey and Traditional Practices of Folkloric Populaces in and around Parvathamalai Hills and 126 species recorded.

The study identified 105 medicinal plants used to treat approximately 125 human ailments. Among these, seven plants are commonly utilized for managing cold and cough symptoms. Six plants are employed for conditions such as fever, stomachache, headache, wounds, bruises, boils, and ear ailments. Additionally, five plants are specifically used to address rheumatic or joint pain, bowel disorders, and snake bites. The primary therapeutic effects of these plants include their anti-inflammatory properties, followed by their effectiveness in treating respiratory disorders and enhancing digestive health. Many of these plants also demonstrate efficacy in treating skin conditions and possess antioxidant properties that are beneficial for managing severe diseases. Similarly, Sureshkumar *et al.* [15] documented an ethnopharmacological analysis of medicinal plants used by the Adiyar community in the Wayanad district of Kerala.

The present study identified 105 medicinal plants used to treat 125 different ailments, with cough being the most commonly addressed condition, managed by seven plant species. Ethnobotanical research conducted in the Tirunelveli district and nearby areas similarly highlights the extensive use of medicinal plants. For instance, 67 species were documented in the Karayar tribal village [16], while 70 species were reported in Subramaniapuram [17]. Research by Iyyanar and Ignacimuthu recorded 90 ethnobotanical plant species utilized by the Kani tribes in the Tirunelveli Hills [18], and 80 ethnomedicinal species were reported in the district overall [19]. Furthermore, Ignacimuthu *et al.* [20] documented 101 medicinal plants employed by the Paliyar tribals in the Theni district, and Iyyanar and Ignacimuthu [21] identified 54 species used by the Kani tribes in Kouthalai, Tirunelveli Hills. Ragupathy and Newmaster [22] also reported 53 ethnobotanical taxa used by the Irula community in the Kodiyakarai Reserve Forest, underscoring the biodiversity and medicinal relevance of the region.

In the neighboring Kanniyakumari district, several studies have documented the rich utilization of medicinal plants. Key findings include 47 species identified in Thengapattanam [23], 86 ethnomedicinal plants recorded in the Vellambi Forest [24], and 71 species traditionally used by the Kani tribes of Mudavanpothai [25]. Additionally, 150 medicinal herbs were cataloged in Agastheeswaram Taluk [26], 64 wild plants documented in Ganapathipuram [27], 101 ethnomedicinal species reported in Attoor [28], and 153 species utilized by the Vetans community in Shankaranputhur village [29]. Jayakumar *et al.* [30] further highlighted 70 plant species and their associated ailments, emphasizing the district's vast repository of traditional medicinal knowledge.

4. Conclusion

In conclusion, the ethnobotanical study in Arugankulam Village, Tirunelveli District, highlights the critical role of traditional healers in utilizing medicinal plants for local healthcare. The research documented a diverse range of plant species used for treating various ailments, emphasizing the community's extensive botanical knowledge. These findings underline the importance of preserving indigenous knowledge and exploring the pharmacological potential of these plants. Integrating traditional practices with modern medicine could enhance healthcare access and promote sustainability. However stringent steps have to be taken to check indiscriminate use of this ethnobotanical wealth. For this, the Government should take steps to support traditional healers and at the same time foster collaboration with scientific research which can lead to innovative treatments, safeguard cultural heritage, and conserve regional biodiversity.

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Panchagavya: Nature's Gift for Sustainable Living

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ABSTRACT

Panchagavya, a traditional Indian formulation derived from five key cow-based components—cow dung, urine, milk, curd, and ghee represents a sustainable approach to environmental and agricultural practices. This study investigates the preparation and diverse applications of Panchagavya-based products, including Panchagavya fertilizer, neem-infused Panchagavya pesticide, solid and liquid variants of Panchagavya pesticides, Panchagavya vilakku, Sambrani, Utupatti, tooth powder, soap oil, and soap. These innovations are utilized in organic farming, household applications, and personal care. Panchagavya has been shown to enhance soil fertility, improve crop growth and yield, reduce reliance on chemical inputs, and contribute to environmental sustainability. Furthermore, it strengthens plant immunity, making crops more resilient to pests and diseases. This research highlights the multifaceted benefits of Panchagavya as a viable solution for promoting organic agriculture, human health, and ecological conservation, while calling for further scientific studies to validate its efficacy and expand its global adoption.

Keywords: Panchagavya, homemade products, sustainable agriculture, organic farming

1. Introduction

Panchgavya, an age-old Indian tradition, leverages the therapeutic and agricultural benefits of five cow-derived products: milk, ghee, urine, dung, and curd. Celebrated in Indian culture, the cow is venerated as "Gaumata" and "Kamadhenu" due to its vital contributions. Panchgavya has been extensively utilized in Ayurveda for its medicinal properties in addressing various health conditions. In addition to its significance in traditional medicine, Panchgavya has gained recognition in organic farming as an effective natural bio-fertilizer and pesticide, highlighting its holistic and sustainable applications in health and agriculture [1].

Traditional agriculture has long been regarded as a collaborative endeavor between humans and cattle. In recent years, there has been growing interest in the utilization of individual animal products and their formulations. Among these, Panchagavya has gained significant attention as one of the most prominent and widely discussed preparations. The term "Panchagavya" refers to a blend of five products derived from the cow-milk, curd, ghee, urine, and dung. This formulation, deeply rooted in Ayurvedic tradition, is celebrated for its diverse applications in agriculture, medicine, and sustainable practices [2].

This article aims to promote the use of "Panchagavya Therapy/Chikitsa" as an alternative prophylactic and therapeutic approach for improving livestock and poultry health, as well as human well-being, while honoring the sacred role of the cow in the ecological chain [3]. Panchagavya products have demonstrated effectiveness in treating various human ailments and enhancing immunity, thereby boosting the body's resistance to infections [4]. The article discusses the composition, functions, health benefits, and medicinal properties of Panchagavya products, supported by available scientific evidence [5]. Additionally, Panchagavya is highlighted as an economical, eco-friendly solution with no known side effects, making it a sustainable choice for health and agriculture [6].

This study emphasizes the diverse applications, benefits, and significance of Panchagavya in daily life, supported by established scientific evidence. The primary aim is to explore and develop Panchagavya-based products, including natural bio-fertilizers and pesticides, to enhance crop productivity, promote biodiversity, and improve soil fertility. These innovations aim to provide farmers with cost-effective and eco-friendly solutions, contributing to sustainable agriculture and better livelihoods. Additionally, the research focuses on creating household products such as soaps and Sambrani, offering environmentally friendly alternatives for human use while supporting ecological well-being.

2. Materials and Medods

Materials of Panchagavya

Cow-derived products include dung, urine, milk, curd, and ghee.

Methods of Preparing Panchagavya

Collection: Gather fresh and high-quality cow-derived products, ensuring their purity and cleanliness for optimal effectiveness.

Mixing: Combine the collected ingredients—cow dung, cow urine, cow milk, curd, and ghee in precise proportions to achieve the desired composition and balance.

Fermentation: Allow the mixture to undergo fermentation over a specified period, creating an environment for the growth of beneficial microorganisms that enhance its properties.

Straining: Once fermentation is complete, strain the mixture to remove any solid residues, resulting in a nutrient-rich liquid ready for use.

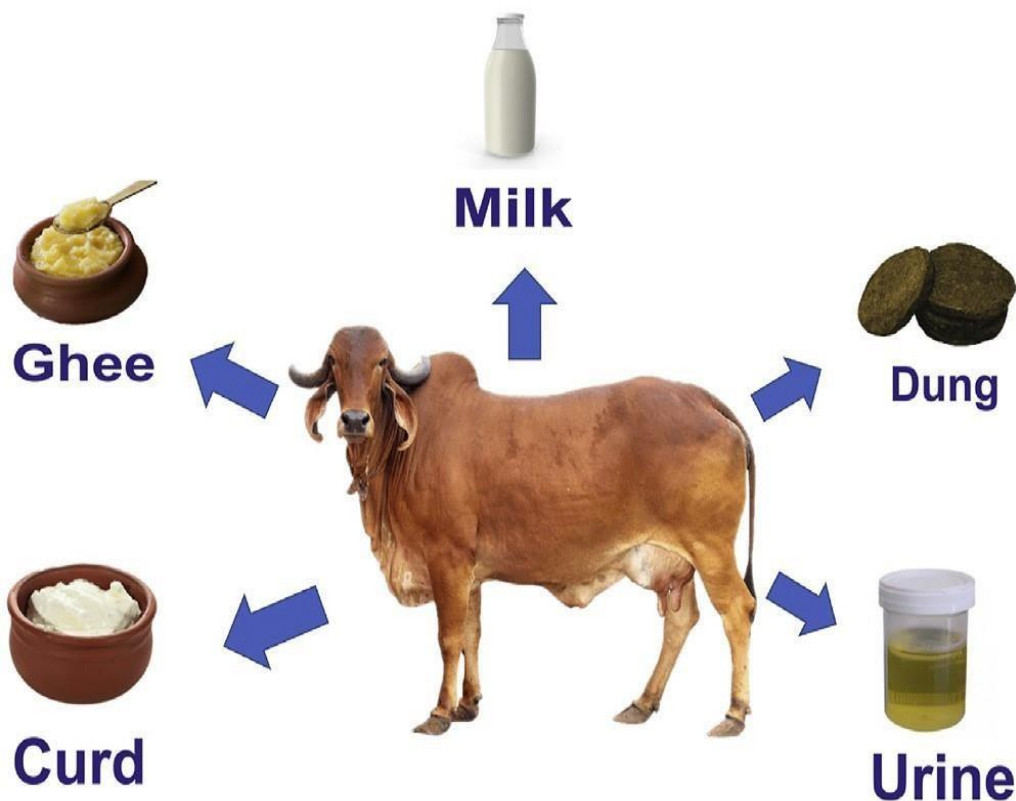


Fig. 2.1. Components of Panchagavya

Table 1. Ingredients And Preparation of Panchagavya Products

No.	Materials	Methods
1.	Ingredients And Preparation of Panchagavya Fertilizer	
	Cow dung - 2 kg Cow ghee - ½ kg Cow Urine - 2 litres Cow milk - 1 litres Cow curd - 1 litres Water - 2 litres Jaggery - 1 kg Sugar Cane - 1 kg Tender coconut water - 1 litre Well ripened poovan banana - 12 nos.	<p>To create Panchagavya fertilizer, begin by combining 2 kg of cow dung with 0.5 kg of cow ghee in a wide-mouthed clay pot. Place the mixture in a shaded area and cover it with a wire mesh or plastic mosquito net to prevent contamination by houseflies. Allow the mixture to ferment for 7 days in the shade, stirring it twice daily—once in the morning and once in the evening.</p> <p>After the initial fermentation period, transfer the mixture to airtight containers and store them in a cool, shaded place. Open the lid every two to three days to release gases formed during ongoing fermentation. Separately, mix 2 liters of cow urine with 2 liters of water and allow this solution to sit for 15 days, stirring it regularly, morning and evening.</p> <p>After 15 days, add the following ingredients to enhance the fermentation process and minimize any unpleasant odor: 1 liter each of cow milk, cow curd, and tender coconut water; 1 kg of jaggery; 1 kg of sugarcane; and 12 fully ripe Poovan bananas. The Panchagavya stock solution will be ready for use after a total of 30 days.</p>

2.	Ingredients And Preparation of Panchagavya Herbal Fertilizer	
	<p>Cow dung - 2kg Cow urine - 2lt Cow milk - 1lt Cow ghee - 500g Cow curd - 1lt <i>Lantana camara</i> -500g <i>Pongamia pinnata</i> - 500g <i>Datura metel</i> - 500g <i>Adathoda vasica</i> -500g <i>Vitex negundo</i> - 500g <i>Calotropis gigantea</i>-500g <i>Jatropha curcas</i> - 500g <i>Leucas aspera</i> - 500g <i>Azadirachta indica</i> - 500g</p>	<p>To prepare the Panchagavya solution, mix the following ingredients: 2 kg of cow dung, 2 liters of cow urine, 1 liter of cow milk, 500 g of cow ghee, and 1 liter of cow curd. Additionally, collect 500 g each of the following plants: <i>Lantana camara</i>, <i>Pongamia pinnata</i>, <i>Datura metel</i>, <i>Adathoda vasica</i>, <i>Vitex negundo</i>, <i>Calotropis gigantea</i>, <i>Jatropha curcas</i>, <i>Leucas aspera</i>, and <i>Azadirachta indica</i>.</p> <p>Plant extracts are prepared by soaking the foliage of these plants in cow urine in a 1:1 ratio for 10 days. Once fermented, the extracts are filtered and added to the Panchagavya solution at the rate of 1 liter of each extract to 5 liters of the solution. The mixture is then left to ferment for 25 days, with regular stirring to ensure uniform blending.</p> <p>After 25 days, the Panchagavya solution is filtered to remove solid residues, preventing clogging in sprayer nozzles. The resulting herbal fertilizer is ready to be applied to plants and used as a foliar spray.</p>
3.	Preparation of Panchagavya Vilakku	
	<p>Cow Ghee - 10 g Cow dung - 500 g Cow urine - 250 ml Cow Milk -100 ml Cow Curd - 100 ml Cotton wick</p>	<p>To prepare the Panchagavya Vilakku, gather the following ingredients: 10 g of cow ghee, 500 g of cow dung, 250 ml of cow urine, 100 ml of cow milk, and 100 ml of cow curd. You will also need a cotton wick.</p> <p>Start by cleaning and preparing the lamp. In a separate container, mix 1 part cow ghee with 2 parts powdered cow dung to create the base for the lamp. Add a few drops of cow urine to the mixture and stir thoroughly.</p> <p>Once the base is ready, pour in the cow milk and curd, filling the lamp to about three-quarters of its capacity. Place the cotton wick in the center of the lamp.</p> <p>Finally, light the wick, and the Panchagavya Vilakku is now ready for use.</p>
4.	Preparation of Panchagavya Panchagavya Sambrani	
	<p>Cow dung - 500 g Cow urine - 250 ml Cow milk - 100 ml Cow ghee - 10 g Cow curd - 100 g Sambrani - 50 g Karpuram - 50 g</p>	<p>To make Panchagavya Sambrani, gather the following ingredients: 500 g of cow dung, 250 ml of cow urine, 100 ml of cow milk, 10 g of cow ghee, 100 g of cow curd, 50 g of sambrani, and 50 g of camphor (karpuram).</p> <p>Begin by drying the fermented LP mixture. Once dry, combine it with turmeric powder, neem oil, or neem leaves to boost the effectiveness of the Panchagavya Sambrani.</p> <p>After thoroughly mixing, store the preparation in an airtight container to maintain its potency. The Panchagavya Sambrani is now ready for use.</p>
5.	Preparation of Panchagavya Neem – Based Pesticides	
	<p>Neem leaves /seeds Panchagavya Water</p>	<p>To prepare a Neem-Based Panchagavya Pesticide, begin by gathering 1 kg of fresh neem leaves. Wash the leaves thoroughly, dry them, and grind them into a fine powder. Next, combine 100 g of the neem powder with 1 liter of liquid</p>

	Soap / emulsifier Storage containers Sprayer / drencher	Panchagavya. Add 10 ml of soap or another emulsifier to the mixture and stir well to ensure all ingredients are fully blended. Once prepared, transfer the pesticide to an airtight container to maintain its effectiveness. The Neem-Based Panchagavya Pesticide is now ready for application.
6.	Preparation of Panchagavya Solid Panchagavya Pesticide	
	Cow dung - 500 g Cow urine - 250 ml Cow milk - 250 ml Cow ghee - 25 g Cow curd - 100 ml Neem powder - 50 g Turmeric powder - 25 g	To prepare Solid Panchagavya Pesticides, begin by gathering the following ingredients: 500 g of cow dung, 250 ml of cow urine, 250 ml of cow milk, 25 g of cow ghee, 100 ml of cow curd, 50 g of neem powder, and 25 g of turmeric powder. Start by mixing 100 g of neem powder with 1 kg of solid Panchagavya. Then, add 50 g of turmeric powder and 20 g of red chili powder to the mixture. Stir all the ingredients thoroughly until a uniform blend is achieved. Finally, store the prepared Soil Panchagavya Pesticides in an airtight container to maintain its potency and effectiveness.
7.	Preparation of Panchagavya Uthupatti	
	Cow urine Cow dung Cow milk Cow ghee Curd Water Wooden spoon Mud pot / ceramic container	To prepare Panchagavya Uthupatti, begin by gathering fresh cow urine, dung, milk, ghee, and curd. Dry the cow dung in a shaded area and grind it into a fine powder. Boil the cow milk and allow it to cool. In a mud pot or ceramic container, combine 1 liter of cow urine, 1 kg of powdered cow dung, 1 liter of cooled cow milk, 100 g of cow ghee, and 100 g of curd. Add 2 liters of water to the mixture. Heat the mixture on a low flame, stirring continuously, until it thickens and reduces to a quarter of its original volume. This step is essential for the preparation of Panchagavya Uthupatti. Once the mixture has cooled, transfer it to an airtight container to preserve its potency.
8.	Preparation of Panchagavya Tooth Powder	
	Cow dung Cow urine Cow milk Cow ghee Curd Neem powder Turmeric powder Triphala powder Salt	To prepare a natural tooth powder, begin by drying cow dung in the shade and grinding it into a fine powder. In a separate bowl, mix cow urine, cow milk, cow ghee, and curd. Add the powdered cow dung, neem powder, turmeric powder, triphala powder, and salt to the mixture. Thoroughly blend all the ingredients until a uniform consistency is achieved. Next, allow the mixture to dry in the shade for 2-3 days to eliminate excess moisture. Once fully dried, sieve the powder to remove any lumps, resulting in a smooth and effective natural tooth powder.
9.	Preparation of Panchagavya Soap	

	Cow dung - 500 g Cow urine - 250 ml Cow milk - 250 ml Cow ghee - 25 g Cow curd - 100 ml Neem powder - 50 g Turmeric powder - 25 g	Start by mixing 1 liter of Panchagavya with 1 liter of distilled water. Heat 500 g of coconut oil to 40°C. In a separate container, dissolve 100 g of alkali in 200 ml of distilled water. Gradually add the alkali mixture to the heated oil, stirring gently. Next, incorporate the Panchagavya mixture and blend thoroughly. Add a few drops of essential oils for fragrance and additional benefits. Finally, pour the mixture into a soap mold and allow it to set.
10.	Preparation of Panchagavya Soap Oil	
	Cow dung Cow urine Cow milk Cow ghee Curd Coconut oil Palm oil Olive oil Lye (sodium hydroxide) Distilled water Essential oil	<p>Begin by preparing the Panchagavya mixture. Dry the cow dung in a shaded area and grind it into a fine powder. In a bowl, combine cow urine, cow milk, cow ghee, and curd. Add the powdered cow dung to the mixture, stir well, and allow it to sit for 24 hours.</p> <p>Next, prepare the oil blend by mixing coconut oil, palm oil, and olive oil in a separate bowl. In another well-ventilated area, mix lye with distilled water, stirring until the lye is completely dissolved.</p> <p>To make the soap, gradually add the lye solution to the oil blend while stirring continuously. Then, incorporate the Panchagavya mixture into the oil-lye blend, stirring until the mixture achieves a uniform consistency. Pour the mixture into a soap mold.</p> <p>Allow the soap to cure for 21-28 days. Once cured, cut the soap into bars. Your Panchagavya Soap Oil is now ready for use.</p>

3. Results

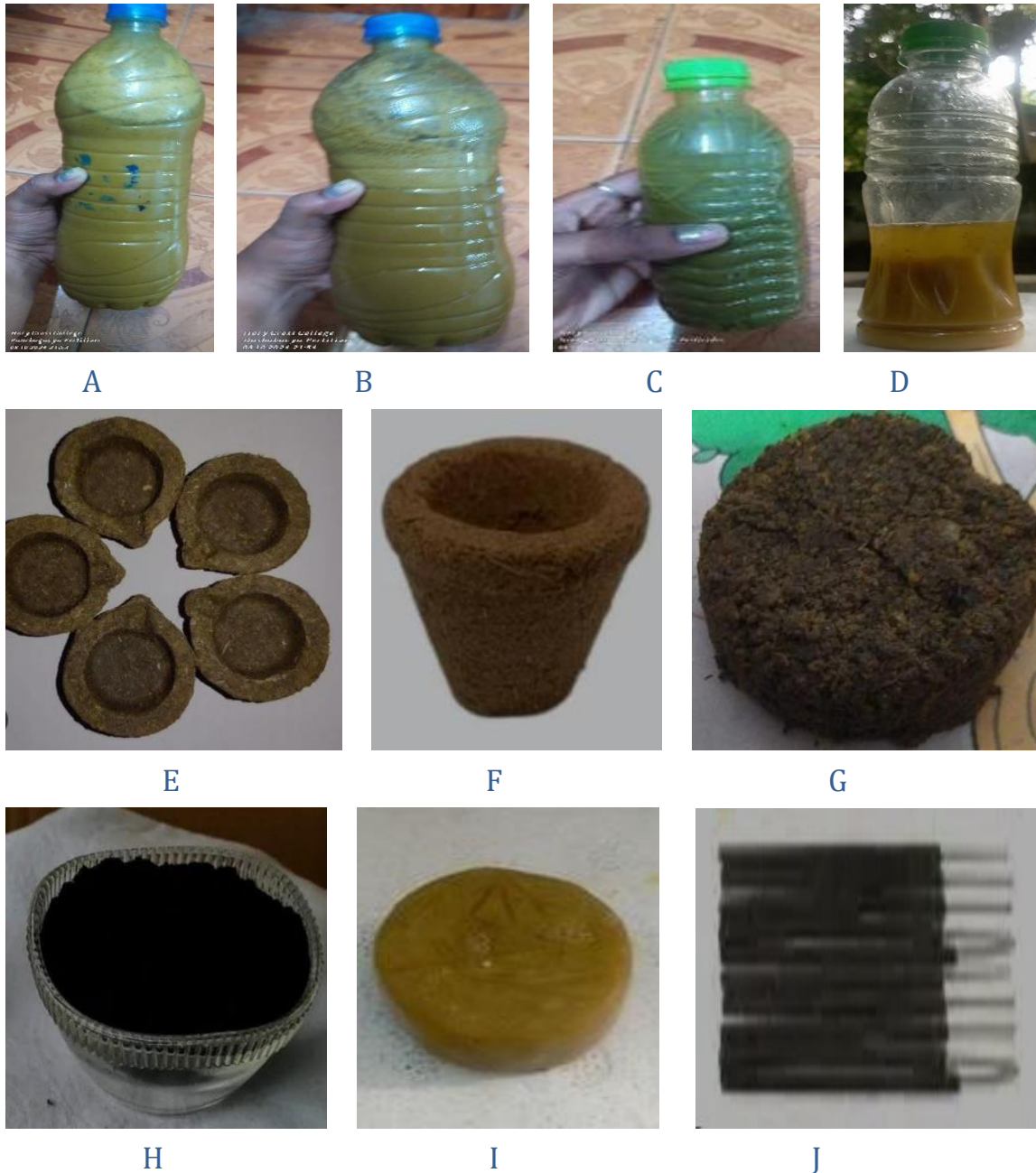
In this study, various Panchagavya-based products were developed, including Panchagavya fertilizer, herbal fertilizer, lamp (vilakku), incense (sambrani), incense sticks (uthupathi), tooth powder, soap, and soap oil. The research further investigated their potential applications, therapeutic benefits for human health, eco-friendly nature, and significance in fostering sustainable agricultural practices. The composition, functions, health benefits, and medicinal properties of each Panchagavya product are detailed in Plate 1 & Table 2.

Table 2. Composition, Functions, Health Benefits and Medicinal Effects of each Panchgavya Products

Sl. No	Materials	Functions	Composition	Health benefits	Medicinal effects
1.	Cow Dung	Soil condition and fertilizer, Improve soil structure and water-holding capacity, Supports beneficial microorganisms, Provides essential nutrients (NPK and	Minerals, Vitamins Nitrogen, Potassium, oxygen, Cellulose, Hemicellulose, Mucus, Lignin	Increase Soil Fertility, Promote worm Growth, Organic manure Gobar Gas Plant Preparation of Herbal Tooth Paste	Antifungal, Antibacterial, Skin tonic, Antimalarial, Anti-TB, Increase Vision, Treat Boils and heal rashes, Treat psoriasis and

		micronutrients)			Eczema
2.	Cow Urine	Antibacterial and antifungal properties, Stimulates plant growth and developments, Enhances soil fertilities, Repels pests and diseases, Provide essential nutrients (NPK and micronutrients)	Urea, Uric Acid, Creatinine, Enzymes, Vitamins A, B, C, D, E, Hormones, Calcium, Iron, Magnesium, Phosphorus	Enhances immunity, detoxifies body, improves digestion, boosts metabolism	Antibacterial, Antifungal, Anticancer, Antioxidant, Antimicrobial, Treats skin diseases, Anti-diabetic
3.	Cow Milk	Provide essential nutrients and amino acids, Stimulated plants growth and water-holding capacity, Supports beneficial microorganism, Provide essential nutrients.	Proteins, Carbohydrates, Fats, Vitamin A, B12, D, Calcium, Potassium, Magnesium, Phosphorus	Promotes bone health, improves vision, enhances immunity, strengthens muscles	Antacid, Anti-inflammatory, Improves gut health, Treats dehydration, Enhances brain function
4.	Cow Ghee	Soil conditioner and fertilizer, Improve soil structure and water-holding capacity, Support beneficial microorganism.	Essential Fatty acids, Omega 3 & 9, Vitamin-A, D, E, K, Short Chain fatty acids	Improves digestive system Immuno modulatory, Prevent CVD, Beauty enhancer, Memory enhancer, Blood purifier	Enhance Vision, Wound healing, Immuno-stimulant, Treat Skin Disease, Anti-asthmatic, Anti-neoplastic, Antiinflammatory Anti-cholinergic
5.	Cow Curd	Provide essential nutrients and amino acid, Stimulates plants growth and developments, Enhance soil fertility	Water, Proteins, Vitamin-A,B,D,E, Ca, P, Mg, Zn	Improves digestive System, Enhance Immune System, Improves Quality of Hair	Antifungal, Anti HIV, Treats Digestive ailments, Decrease obesity, Prevent Piles

Plates 1. Home Made Panchagavya Products



A. Panchagavya fertilizer B. Panchagavya Herbal Fertilizer C. Neem-based Panchagavya pesticide D. Panchagavya Soap Oil E. Panchagavya Velakku
F. Panchagavya Sambrani G. Solid Panchagavya Pesticide H. Panchagavya Tooth Powder I. Panchagavya Soap J. Panchagavya Uthupathi

4. Discussion

Cowdung is antiseptic and possesses antibacterial and fungicidal components. It contains beneficial microbes such as *Saccharomyces*, *Lactobacillus*, *Bacillus*, *Streptococcus*, and *Candida*, which contribute to its effectiveness [7]. Fungal diseases pose a significant

challenge in agriculture, but cow dung can help mitigate issues caused by pathogens like *Fusarium oxysporum*, *Fusarium solani*, and *Sclerotinia sclerotiorum* [8]. Its use in agriculture is vital for maintaining soil health, as it enhances earthworm populations, particularly *Eisenia andrei*, which facilitate nitrification and improve soil fertility [9]. Cow dung also contains essential nutrients such as minerals, vitamins, potassium, nitrogen, oxygen, carbon, cellulose, hemicellulose, mucus, and lignin. Its filtrate, prepared by mixing cow dung with water, is a key ingredient in ointments for treating severe skin conditions like psoriasis, eczema, and gangrene [10]. Additionally, dried cow dung cakes serve as an eco-friendly fuel source for cooking, reducing dependence on alternative energy while purifying the air and eliminating airborne pathogens in rural India. Biogas plants utilize cow dung to produce methane gas, which is used for cooking and electricity generation [5]. Furthermore, cow dung's microbial richness makes it effective for degrading waste from urban and hospital environments [7].

Cow urine, commonly known as "Gaumutra," is a non-toxic liquid excreted by cows and holds significant importance in Ayurvedic texts. Recognized for its medicinal properties, it is traditionally used to treat over 3,000 ailments and severe diseases, enhancing overall quality of life [2]. It has been utilized in addressing conditions such as cancer, diabetes, hypertension, asthma, psoriasis, eczema, ringworm, heart disease, artery blockage, arthritis, thyroid issues, ulcers, constipation, and various gynecological disorders [10], nephroprotective property [7], analgesic activity [11], Anti-haemorrhoid effects [12,13], Antimicrobial activity [14], free radical scavenging activity [15], Anti-cancer effects [13], antineoplastic agent [13,16]. In addition to its therapeutic uses, cow urine mixed with neem leaves serves as an effective biopesticide. Composed of 95% water, 2.5% urea, and 2.5% enzymes, hormones, salts, and minerals, cow urine helps boost the immune system. It also contains essential vitamins, including A, B, C, D, and E, further enhancing its health benefits [2].

According to Ayurveda, cow milk provides unique nourishment that is unmatched by other food sources. It is valued for its extensive medicinal and health benefits, and is often used as a substitute for breast milk in infants. Cow milk plays a crucial role in the development of teeth and bones [17], supports heart health, and has a wide range of therapeutic effects [10]. approximately 4.6% lactose, 4.65% fat, 0.54% minerals, 3.4% proteins, and 86% water. The proteins in cow milk include 27% beta-casein, 9% gamma-casein, 36% alpha-casein, and 27% peptides. Casein constitutes about 3% of the milk and is found in a colloidal form, along with pigments like xanthophyll, carotene, and riboflavin [18].

In addition to these proteins, milk is an excellent source of essential fatty acids, calcium, and phosphorus, and contains phospholipids such as cephalin, lecithin, and sphingomyelin. It also provides vitamins A, B2, B3, and K [18,19]. Cow milk helps inhibit the growth of harmful gut bacteria while promoting beneficial gut flora [20], Milk enzymes like xanthine oxidase, lactoperoxidase, and lysozyme have antibacterial properties, and peptides such as beta-casomorphins, exorphin and seraphim are known for their anti-diarrheal effects [21], Cis-isomer of linoleic acid present has antineoplastic activity. Additionally, the cis-isomer of linoleic acid found in milk has antineoplastic activity, and milk has shown anticancer properties against skin, colon, and breast cancers [22].

Cow curd, also known as yogurt or "Dahi," is a valuable by-product of cow milk, consumed globally for its rich nutritional content and health benefits. Recognized as one of the healthiest foods, it is made by fermenting cow milk with microorganisms such as *Streptococcus*, *Acidophilus*, and *Lactobacillus* [23]. Curd is packed with essential nutrients, including water, proteins, and vitamins A, B, D, and E. It also contains important minerals like calcium, phosphorus, magnesium, and zinc [24]. A significant source of probiotics, curd contains beneficial microorganisms that offer various health benefits when consumed. Lactic acid bacteria in curd produce metabolites such as cyclic dipeptides, phenyl lactic acid, and antifungal compounds. These bacteria also contribute protein-rich compounds and 3-hydroxylated fatty acids, further enhancing its nutritional and therapeutic properties [5,25].

In Ayurveda, cow's ghee is regarded as the most beneficial type of fat for human consumption. Traditionally prepared cow ghee is rich in nutritional value, offers medicinal benefits, and supports overall health. The preparation process involves heating butter derived from cow milk at a high temperature until all moisture is eliminated [26]. It is especially beneficial for individuals with high blood cholesterol, as it is packed with essential nutrients. Regular consumption of cow ghee enhances physical and mental strength, supports bodily health, and promotes vitality. Additionally, it helps detoxify the body and improves eyesight, supports tendon and muscle health, and keeps bones strong yet flexible [10]. Cow ghee, when combined with *Aegle marmelos* leaf extract, has shown to significantly accelerate wound healing within eight days [27,28]. When combined with *Aloe vera*, it also demonstrates wound healing potential within 21 to 24 days. Cow ghee is effective in addressing Computer Vision Syndrome (CVS), a condition causing eye dryness, burning, itching, and redness. Thanks to its vitamin A content and lubricating properties, cow ghee helps maintain moisture on the eye's surface, preventing dryness and vision impairment [11].

Panchagavya is widely used as both a liquid and solid fertilizer, as well as a biopesticide in agriculture, significantly enhancing crop growth and yield. It promotes beneficial soil microorganisms around the plant roots, improving soil fertility by increasing organic matter, macro and micronutrient levels, and nutrient uptake by plants. This helps maintain overall soil health [29]. Spraying panchagavya on plant leaves leads to the growth of larger leaves and a denser canopy, boosting photosynthesis and enhancing the production of metabolites and photosynthates [30]. Additionally, it improves the shelf life, taste, and quality of fruits, grains, and vegetables, while encouraging side shoot development from the trunk, resulting in more fruit-bearing branches. The treatment also strengthens root systems, helping crops stay fresher longer while absorbing more nutrients and water [31].

From an environmental perspective, Panchagavya helps reduce the reliance on chemical inputs, improves soil health, and supports biodiversity. It enhances ecosystem services, reduces water pollution, and contributes to climate change mitigation. Socially, Panchagavya-based products promote food security, improve nutrition and health, empower rural communities, foster social inclusivity, and help preserve traditional knowledge. However, the benefits of Panchagavya should not be confined to ancient texts; scientific research is essential to validate its biological activities, ensure safety, and establish standardized guidelines. Rigorous experimentation is necessary for each product to confirm its composition, chemical properties, pharmacological effects, safety, toxicity profile, and the mechanisms through which its active components function. Additionally, it is crucial to raise public awareness and promote Panchagavya products to garner global recognition of India's rich traditional practices and knowledge.

5. Conclusion

In this study, several products were developed using Panchagavya, a traditional organic formulation. These products include Panchagavya fertilizer, herbal fertilizer, lamps, incense, tooth powder, soap, and oil. Panchagavya-based products are not only environmentally friendly but also show potential for therapeutic applications, benefiting both human health and the environment while promoting sustainable organic farming practices. Overall, this article highlights that integrating organic farming with traditional inputs like Panchagavya provides a viable, sustainable alternative to conventional farming, supporting healthier food production and contributing to environmental preservation.

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Generative AI in Academia: Tools, Transformative Impacts and Ethical Considerations

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ABSTRACT

The integration of artificial intelligence (AI), particularly generative AI, is significantly transforming the academic landscape. It has introduced a wide range of innovative tools that enhance research processes and outcomes. This paper provides an in-depth examination of the various tools of generative AI. These tools have the potential to boost research efficiency, reduce workloads, and elevate the quality of scholarly output. This paper takes into consideration few of the generative AI tools available that is helpful for the academicians. It analyses the transformative impact of AI-powered tools that is evident in empowering researchers to explore complex data, communicate findings effectively, and streamline research processes. This paper also underscores the need for a balanced approach to leverage AI's benefits while addressing its ethical and practical challenges to maximize its positive contributions to academia.

Keywords: Artificial Intelligence, Generative AI, Ethics, Academia, Research,

Introduction

The integration of Artificial Intelligence (AI) into academia is transforming the way research is conducted, communicated, and applied. Among the most impactful innovations in AI is generative AI, a branch of AI that specializes in creating content such as text, images, and simulations. From automating repetitive tasks to generating creative insights, generative AI is reshaping traditional academic workflows and expanding the horizons of scholarly exploration.

Generative AI tools like GPT models for text generation, DALL·E for image synthesis, and automated coding assistants have emerged as invaluable resources for researchers and educators alike. These tools enable academicians to process complex data, draft high-quality papers, and visualize abstract concepts more effectively. For instance, natural language models can assist in literature reviews, while generative design tools enhance visualization in engineering and the sciences. Such innovations promise not only to improve efficiency but also to democratize access to advanced research capabilities.

However, the adoption of generative AI in academia also introduces significant ethical and practical challenges. Concerns over data privacy, potential biases in AI-generated outputs, and questions surrounding intellectual property ownership highlight the need for a cautious and balanced approach. Moreover, there is an ongoing debate about how reliance on AI might affect the development of critical thinking and creativity in academic settings.

This paper explores the transformative impact of generative AI on academic research, focusing on key tools and their applications. It also addresses the ethical considerations and challenges associated with this technology, emphasizing the importance of responsible integration to maximize its positive contributions to academia. By doing so, the study seeks to provide a comprehensive perspective on the opportunities and limitations of generative AI in reshaping the future of academic scholarship.

Related Works

The fast growth of generative AI has led to many studies about its uses, benefits, and ethical issues. This review summarizes important findings, focusing on ethics, societal impacts, and challenges in using generative AI.

The development of generative models, particularly deep learning architectures like Generative Adversarial Networks (GANs) [1] and Transformer-based models such as OpenAI's GPT series, has expanded AI's capabilities in creating text, images, audio, and video. Research by Radford et al [2] highlights the versatility of GPT models in generating clear and relevant text, while Ramesh et al [3] demonstrate DALL·E's success in generating high-quality, creative images from textual descriptions. These innovations are lauded for their potential in fields such as content creation, medical research, and education.

Floridi et al [4] outlay the socially beneficial outcomes of AI by identifying key opportunities and risks. They have also formulated five ethical principles and 20 action points to guide AI adoption and address pressing social challenges through collaboration.

Cath et al [5] compares AI governance frameworks across regions with a focus on ethical implementation and have cautioned that one must ensure new smart technologies serve the human agenda, rather than humans serving the needs of these technologies.

European Commission Report [6] on The Ethics Guidelines for Trustworthy AI constitute guidelines which provide a helpful tool for AI practitioners to assess and improve their AI systems in the European Union.

Bender et al [7] present the costs and risks of larger language models (LMs) and urge researchers to carefully assess whether the benefits of advancing LMs outweigh the significant risks including bias and societal harms.

Although the literature addresses several critical aspects of generative AI, gaps remain in understanding long-term societal impacts, cross-cultural ethical considerations, and the scalability of governance mechanisms. Furthermore, interdisciplinary collaboration between technologists, ethicists, policymakers, and industry stakeholders is needed to ensure holistic solutions. This survey establishes the groundwork for further exploration of ethical considerations and challenges in generative AI. The existing research emphasizes the need for proactive steps to ensure generative AI is used responsibly and fairly.

Working of Generative AI

Generative AI uses various techniques—including neural networks and deep learning algorithms—to identify patterns and generate new outcomes based on them. The training process for a generative model involves feeding it a large dataset of examples, such as images, text, audio, and videos. Then, the model analyzes the patterns and relationships within the input data to understand the underlying rules governing the content. It generates new data by sampling from a probability distribution it has learned. And it continuously adjusts its parameters to maximize the probability of generating accurate output [8].

For example, a generative model trained on a dataset of cat images could be used to create new images of cats by sampling from the learned distribution and then refining the output through a process called “inference”.

During inference, the model adjusts its output to better match the desired output or correct any errors [9]. This ensures that the generated output becomes more realistic and aligns better with what the user wants to see. Table 1 presents a brief analysis of popular AI tools that can be adopted for educational purposes.

Table 1. AI Tools for Creative and Educational Purposes

Tool Name	Owner	Capabilities	Students' Point of Interest	Reference Website Link
OpenAI GPT	OpenAI	Natural Language Generation, Text Completion	Understanding language, Creative writing	openai.com/gpt
DeepArt	DeepArt.io	Artistic Style Transfer, Image Generation	Digital art, Image manipulation	deepart.io
DALL-E OpenAI	OpenAI	Image Generation from Text	Creative design, Visual storytelling	openai.com/dall-e
RunwayML	RunwayML	Various (text, image, sound, etc.)	Creative projects, Rapid prototyping	runwayml.com
Nvidia GauGAN	Nvidia	Image Synthesis	Landscape design, Digital art	nvidia.com
Google Magenta	Google	Music Generation, Image and Audio Processing	Music composition, Creative expression	magenta.tensorflow.org
Canva AI	Canva	Graphic Design, Image Manipulation, Branding Tools	Marketing, Content Creation	canva.com
ChatGPT	OpenAI	Conversational AI, Problem Solving	Academic assistance, Idea generation	chat.openai.com
Adobe Firefly	Adobe	Generative AI for Images, Design Enhancements	Graphic design, Visual effects	adobe.com
Grammarly	Grammarly Inc.	Grammar and Style Checking, Writing Assistance	Writing improvement, Language learning	grammarly.com

IBM Watson Studio	IBM	Data Analysis, Machine Learning, Predictive Models	Data science, AI model building	ibm.com
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Ethical Considerations in Ai Integration in Education

In the rapidly evolving field of AI, generative AI technologies like ChatGPT are changing how we engage with technology. Similarly, conversational agents such as Apple's Siri, Google Assistant, Amazon's Alexa, Bard, IBM's Watson, Microsoft's Cortana, and Samsung's Bixby are becoming more advanced. As these systems develop, concerns regarding their ethical use and societal impact grow, highlighting the necessity for responsible usage. Challenges in AI systems arise from the need to protect against potential threats and ensure individuals are safeguarded from AI-generated decisions that may compromise their well-being.

Twinomurinzi and Gumbo [10] identified three main non-technology areas of focus in research involving ChatGPT: 'human,' 'ethics,' and 'decision-making.' In response to these concerns, academic publishing has begun promoting the responsible use of AI tools by implementing clear guidelines. Reaching an agreement on the regulation of chatbots in scientific writing is crucial. The application of ChatGPT in education spans multiple disciplines, and notable research has shed light on its unique integration into educational settings.

Lund and Wang [11] provide insights into scholarly publishing, while many contributions focus on scientific research, demonstrating ChatGPT's wide-ranging academic applications. Yan explores its role in second language (L2) learning, and Ray et al. [12] examine its impact on customer service, healthcare, and education. While recognizing AI's transformative potential, various studies warn against ignoring ChatGPT's limitations, such as factual inaccuracies and biases, unequal access to AI-driven analytics, learning stagnation, discriminatory outcomes, privacy violations, and harmful content generation, along with the overall potential risks and ethical dilemmas.

Additionally, Akgun and Greenhow [13] noted that despite AI's advantages for learning and teaching, its ethical and societal drawbacks are often neglected in K-12 education. These challenges should be acknowledged and addressed for both teachers and students. Given these concerns, stakeholders advocate for coherent regulations and ethical guidelines in educational contexts. Therefore, our study aims to explore the integration of

generative AI in the educational sector by investigating the decision-making framework for utilizing ChatGPT in this environment.

Conclusion

The paper has made an in-depth analysis of the various applications of generative AI in academic settings highlighting both the opportunities and challenges that lie ahead in front. However, like any technological advancement, these innovations come with inherent limitations. Issues related to accuracy, ethical considerations, linguistic comprehension, contextual understanding, critical thinking emulation, appropriate data visualization, necessary training, and keeping up with recent research present challenges that require careful attention and resolution. Effectively addressing these obstacles will be crucial for maximizing AI's potential in academia while maintaining the integrity and ethical standards of scholarly work.

Despite these difficulties, the impactful contributions of AI-powered tools are undeniably reshaping the academic landscape and empowering researchers to explore complex data, communicate findings effectively, and streamline research processes.

As access to AI becomes widespread, it is essential that as teachers, researchers and organizational citizens, we embrace the generative AI technology but that we do this in a wise, critical and ethically responsible manner, aware of the associated implications and risks for the quality and meaningfulness of our work and, indeed, for its very existence.

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Empowering Healthcare Data Analytics: Streamlit for Streamlined Application Development and Visualization

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ABSTRACT

This paper discusses how Streamlit can improve healthcare data analytics by simplifying application development and enhancing data visualization. Streamlit is an open-source Python framework that allows quick creation of interactive web applications without complex front-end programming. In healthcare, it helps analyze large datasets, create real-time visualizations, and provide valuable insights for medical professionals, researchers, and decision-makers. By connecting healthcare data with Streamlit's easy-to-use interface, the system enables users to visualize patient trends, track health outcomes, and make better decisions. The paper explains how Streamlit can simplify the development of customized tools for healthcare providers, improving patient care and efficiency. It also shows how real-time data updates, interactive dashboards, and machine learning models can support better decision-making in healthcare. This study demonstrates how Streamlit can turn raw healthcare data into useful insights, offering a user-friendly platform for better decision support and collaboration.

Keywords: Streamlit, Healthcare Data Analytics, Data Visualization, Machine Learning

1. Introduction

The healthcare industry generates vast amounts of data daily, ranging from patient records and clinical trials to medical imaging and administrative details. This data holds significant potential for improving patient care, streamlining operations, and advancing research. However, harnessing the power of this data is often a complex and time-consuming process due to the challenges of data integration, analysis, and visualization. Healthcare professionals and researchers require tools that allow them to quickly analyze and interpret large datasets to make informed decisions.

In recent years, Streamlit, an open-source Python framework, has emerged as a powerful tool for simplifying the development of interactive web applications. Its ease of use and focus on rapid prototyping have made it particularly suitable for data-driven applications in fields like healthcare. Streamlit allows users to create custom applications with interactive visualizations, helping to transform raw healthcare data into actionable insights.

This paper explores the potential of Streamlit in healthcare data analytics, focusing on how it can streamline the development of applications for analyzing healthcare data and visualizing key trends. By eliminating the need for complex front-end development, Streamlit empowers healthcare professionals and data scientists to rapidly build and deploy applications that support decision-making. Furthermore, the integration of real-time data updates, machine learning models, and user-friendly interfaces makes Streamlit a promising tool for enhancing the accessibility and usability of healthcare data. This paper aims to demonstrate how Streamlit can simplify the creation of custom applications that improve patient outcomes, operational efficiency, and research capabilities in the healthcare sector.

Related Works

The article [1] demonstrates how Streamlit simplifies the creation of interactive dashboards and visual analytics, with applications in healthcare and beyond. The paper [2] discusses the use of advanced analytics and visualization in healthcare, emphasizing the need for accessible tools like Streamlit. Demonstrates the use of Streamlit to develop a real-time COVID-19 dashboard for healthcare analytics was demonstrated [3]. How machine learning and visualization tools can improve healthcare insights and decision-making was explored [4].

The research work in [5] analyzes frameworks like Streamlit and their roles in enabling streamlined healthcare analytics applications. Work in [6] reviews the impact of interactive visualization tools in healthcare management and decision support systems. [7] Official documentation providing practical insights into building healthcare-focused analytics and visualization applications using Streamlit. These related works highlight how Streamlit and similar technologies can empower healthcare data analytics, improving visualization, usability, and decision-making processes.

2. Proposed Methodology

The user interface available at present is functional but simplistic, with minimal visual enhancements. Basic filters allow for data exploration, and users can view testing data and time series trends. However, the overall design lacks visual depth and interactivity, limiting the user experience.

The proposed system significantly upgrades the user interface by introducing vibrant gradient backgrounds, enhancing visual appeal and user engagement. Advanced analytical features are added, such as the ability to group data by medical conditions and perform detailed age-group based analysis, providing deeper insights into the data. The system also improves user experience by offering colorful, dynamic visualizations, making data exploration more intuitive and visually engaging. These enhancements make the dashboard more interactive, informative, and suitable for users seeking a comprehensive data analysis in health care.

The system introduces interactive features like tooltips and hover effects for contextual data insights. It also offers customizable options, allowing users to personalize visualizations. These enhancements enhance user engagement and comprehension, making data exploration more meaningful.

Streamlit Data Framework

Streamlit is a Python-based, open-source framework designed to build interactive web applications quickly. It is particularly useful for data scientists and developers who want to create dashboards, data apps, and prototypes without needing expertise in web development.

3. Key Features:

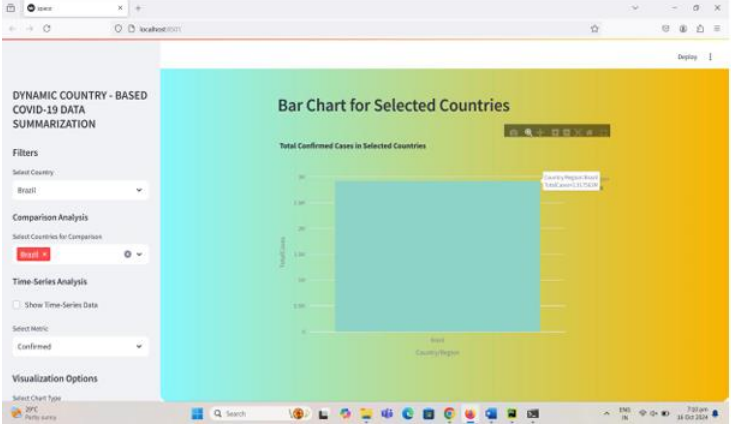
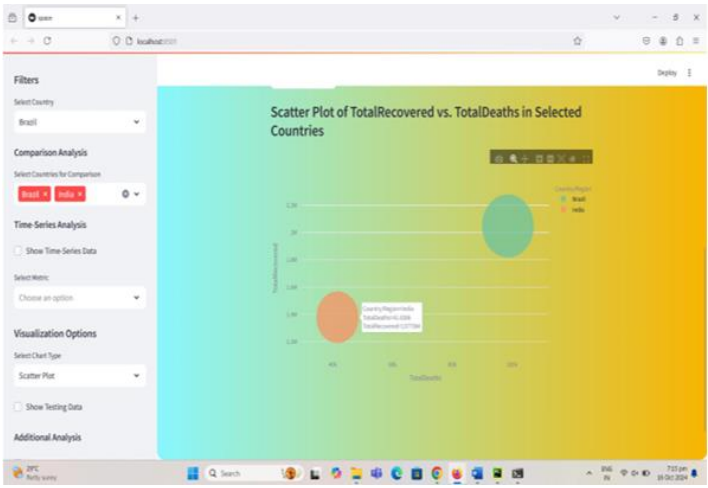
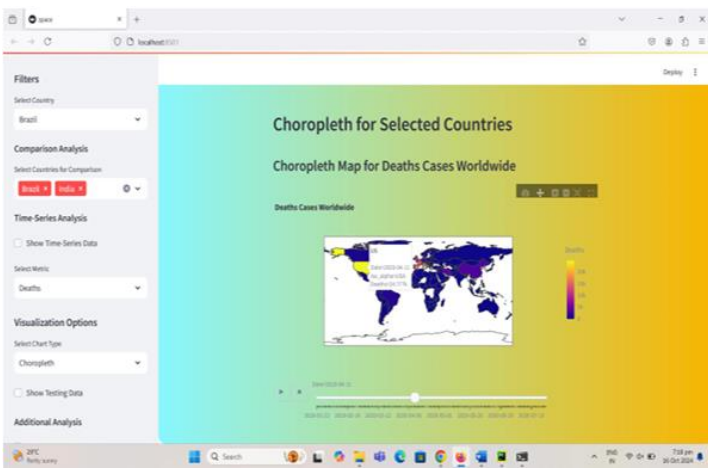
- ❖ **Ease of Use:** Write Python code and Streamlit automatically turns it into an interactive web app.
- ❖ **Real-Time Updates:** Any changes to code or data are instantly reflected in the web app.
- ❖ **Data Visualizations:** Seamless integration with popular libraries like Plotly, Matplotlib, and Altair.


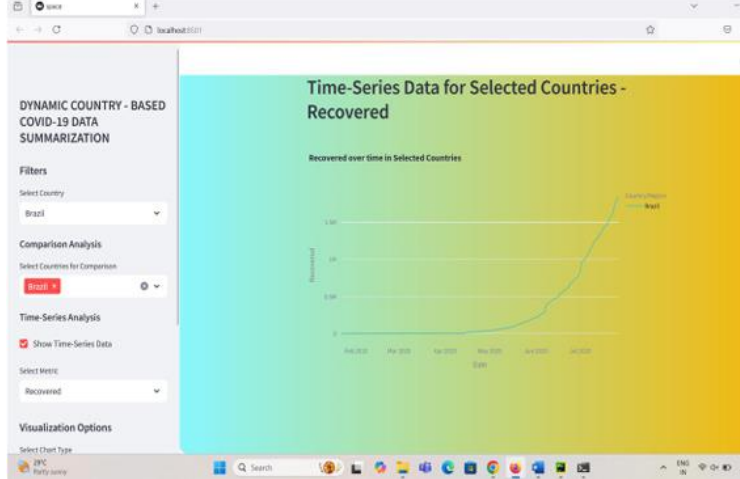
Streamlit's Visualization Features

Streamlit excels in offering user-friendly and interactive visualization tools, making it a powerful platform for presenting complex datasets in an easily understandable format. Key visualization is carried out on the publicly available COVID – 19 dataset [8] and the visualization features, such as bar chart, scatter plot, choropleth map, pie chart and real-time rendering are shown in figure 1.

Fig. 1. Streamlit's Visualization Features

Streamlit's Visualization Features	Explanation	Interactive Visualization Output
Bar Chart	Displays comparisons of	

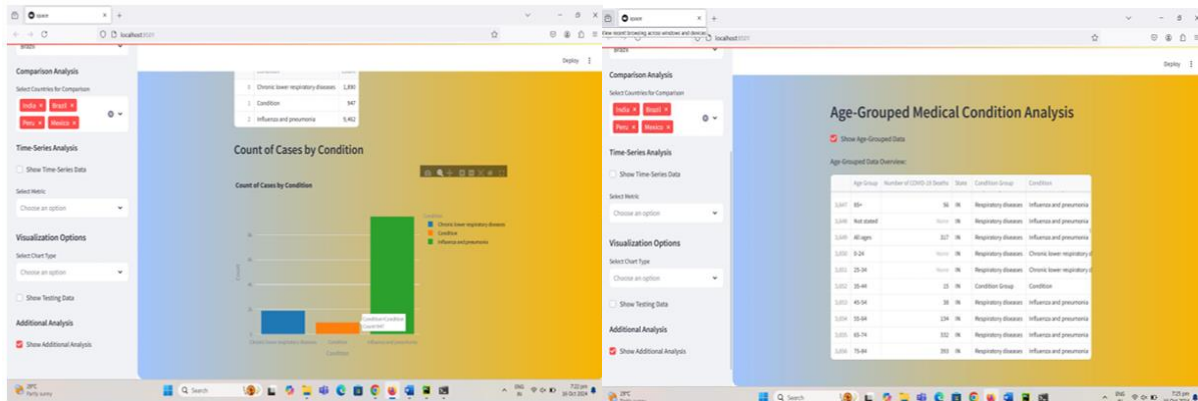
	<p>metrics, such as confirmed COVID-19 cases or deaths, across different countries. Ideal for identifying trends and contrasts in data.</p>	
<p>Scatter Plot</p>	<p>Visualizes relationships between two variables, such as total cases vs. total deaths. Useful for uncovering patterns and correlations in data for deeper analytical insights</p>	
<p>Choropleth Map</p>	<p>Presents geographic data visually, showcasing distributions of cases worldwide by country. Effective for spotting regional trends and global patterns in data.</p>	

Pie Chart	<p>Illustrates proportions of specific metrics, such as the distribution of confirmed cases among selected countries.</p> <p>Helps provide a clear breakdown of how data is segmented.</p>	
Real-time Rendering	<p>Real-time rendering ensures that any updates or changes to the dataset are reflected instantly in the visualizations.</p>	

Customization and Interactivity

Streamlit allows users to tailor visualizations by selecting chart types, adjusting parameters, and focusing on specific data subsets. Its real-time rendering ensures that any updates or changes to the dataset are reflected instantly in the visualizations.

By offering diverse and interactive visualization options, Streamlit empowers users to explore data dynamically, communicate insights effectively, and facilitate informed decision-making. Additionally, it allows for conditional analysis which is evident in figure 2.

Fig. 2. Additional Condition Analysis

While Streamlit is a powerful tool for rapid development and visualization in healthcare data analytics, understanding its limitations is crucial for making informed decisions. The key limitations include limited customization, performance issues, scalability limits, integration challenges, single threaded nature and limited community and ecosystem. Balancing these constraints with its strengths can help in effectively leveraging Streamlit for application specific needs.

4. Conclusion

The integration of Streamlit into healthcare data analytics represents a transformative approach to simplifying application development and enhancing data visualization. By leveraging Streamlit's intuitive interface and interactive capabilities, healthcare professionals and researchers can efficiently analyze and interpret complex datasets, making data-driven decision-making more accessible. This paper highlighted how Streamlit empowers the development of custom analytics tools, enabling real-time insights and fostering collaboration across multidisciplinary teams. Furthermore, the framework's ability to handle diverse healthcare scenarios, from patient monitoring to predictive modeling, demonstrates its potential to improve outcomes while reducing development time and costs. As the healthcare sector continues to generate vast amounts of data, tools like Streamlit provide a pathway toward streamlined analytics, bridging the gap between raw data and actionable intelligence. Future work could explore integrating advanced AI models and ensuring compliance with data privacy regulations, with actionable steps like identifying key use cases, conducting feasibility studies and by developing prototypes to evaluate its performance and accuracy, conducting data privacy audits, using a secure data infrastructure to protect sensitive health care information, paving the way for further innovation in healthcare analytics.

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Real-Time Bus Tracking System for Government Buses: Enhancing Public Transportation Efficiency

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ABSTRACT

This paper proposes a Real-Time Bus Tracking System designed to improve the efficiency of government bus services. The system uses GPS technology to track the location of buses in real time. It provides passengers with accurate information about bus arrival times, reducing waiting times and improving the overall travel experience. The system also helps transit authorities manage the bus fleet by monitoring vehicle performance, detecting delays, and adjusting routes or schedules as needed. This leads to better resource management, lower fuel consumption, and a more sustainable transportation system. By offering reliable and transparent information to both passengers and operators, the system aims to make public transportation more efficient, reliable, and accessible. The paper discusses the design, implementation, and potential benefits of this system.

Keywords: Real-time Bus Tracking, Transport Efficiency, Sustainable Transportation, GPS

1. Introduction

Efficient public transportation systems are crucial for urban development and sustainability. Government-operated buses play a vital role in providing affordable and accessible mobility to millions of people daily. However, challenges such as unreliable schedules, lack of real-time information, and inefficient resource utilization often hinder the effectiveness of these services. Passengers frequently face uncertainty about bus arrival times, which leads to frustration, time wastage, and decreased confidence in public transit.

Advancements in technology, particularly in real-time tracking and data communication, present an opportunity to address these challenges. Real-time bus tracking systems can bridge the gap between service providers and commuters by offering accurate, live updates about bus locations and estimated arrival times. Such systems leverage GPS, IoT (Internet of Things), and mobile technologies to monitor and communicate vehicle movements in real-

time. These innovations not only enhance passenger convenience but also improve operational efficiency by enabling better fleet management and route optimization.

Several studies have explored real-time vehicle tracking systems for public transit. For instance, implementations in cities like Singapore and New York have demonstrated the potential of GPS-based tracking for improving public transportation reliability. Similarly, mobile applications integrating live tracking data have increased user satisfaction by reducing wait times and offering route guidance. However, these systems are often tailored for private or semi-private transit services, with limited focus on government-operated bus networks, which have unique challenges such as larger fleet sizes and stricter budget constraints.

This paper presents a "Real-Time Bus Tracking System for Government Buses" designed to enhance public transportation efficiency. The system incorporates GPS technology, mobile application interfaces, and centralized data management to provide passengers with real-time bus information. It aims to improve commuter experience, reduce waiting times, and optimize bus operations, contributing to a more sustainable and reliable public transit ecosystem. By addressing the specific needs of government-run buses, this research seeks to advance public transportation efficiency and encourage greater reliance on environmentally friendly travel options.

2. Related Works

This research works [1] [2] explores the application of real-time tracking technologies in urban areas and their benefits in enhancing transportation systems. This work demonstrates IoT's role in creating effective vehicle tracking mechanisms with a focus on accuracy and user engagement. This paper [3] describes a GPS-based bus tracking solution aimed at improving passenger experience. Optimizing schedules and improving public transit reliability through real-time GPS integration is explored in [4] [5]. Identifies [6] common hurdles in implementing tracking systems for public buses and proposes innovative solutions. The research work [7] focuses on utilizing real-time data to enhance efficiency in public transportation systems.

3. Proposed Methodology

In many government-run bus services, public transportation systems still rely on static schedules and manual operations. However, delays caused by traffic, roadblocks, or breakdowns often disrupt these fixed timetables. Passengers, lacking real-time updates, face uncertainty at bus stops, unsure of bus arrivals or route changes. The absence of live communication between bus operators and passengers makes public transport appear unreliable, leading to missed buses, long waiting times, and frustration. This inefficiency

discourages public transport use and reduces the effectiveness of government-run bus services.

To address the shortcomings of the existing system, a Real-Time Bus Tracking System is proposed for government buses. The new system will leverage GPS, mobile applications, and web technologies to provide live, real-time tracking of bus locations, estimated arrival times, and route updates. This system not only improves the passenger experience but also enhances the operational efficiency of bus services.

The key component of this proposed system is GPS tracking. GPS technology has revolutionized public transportation and its key contributions include, real-time tracking, route optimization, enhanced safety, improved fleet management and reduced emissions due to minimized idling time. The diagrammatic representation of GPS is shown in figure 1. The three key components of a GPS system are satellites, which serves like stars in the constellation, ground stations that monitor, identify and control satellites and finally the receivers. The receivers constantly listen for signals from the satellites. The Doppler Effect is the fundamental principle used in GPS technology.

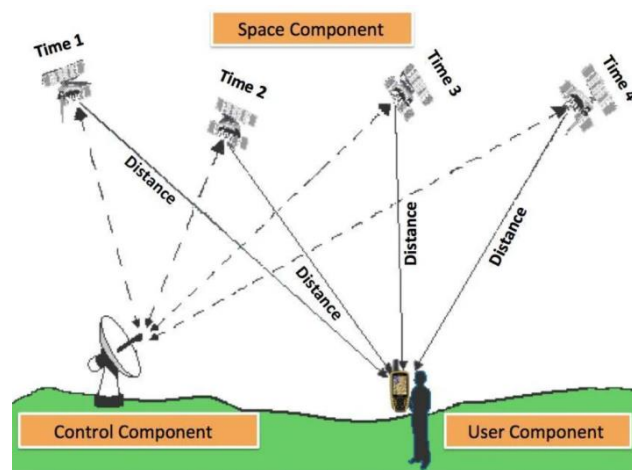


Fig. 1. GPS and its Components

Source: <https://www.armellini.com/post/how-gps-works-step-by-step>

Each bus will be equipped with a GPS device that continuously transmits its location to a central server. This data will then be processed and made available to users through mobile apps, websites, or even digital displays at bus stops. Passengers will be able to track their buses in real-time, see the estimated time of arrival (ETA) for their specific stop, and receive notifications of any delays or route changes. This eliminates the uncertainty of bus arrival times and provides passengers with a more reliable service.

Additionally, the proposed system will introduce route optimization based on real-

time data. Transportation authorities will be able to monitor bus movements, analyze traffic patterns, and adjust routes accordingly. For instance, during peak hours or in the case of heavy traffic, buses can be rerouted to avoid delays, ensuring passengers reach their destinations as efficiently as possible. This dynamic routing system will also allow authorities to better allocate buses to high-demand areas, improving overall service and reducing waiting times. Fleet managers will benefit from this system by gaining access to real-time data about their entire bus network. Through a central dashboard, they will be able to monitor each bus's location, schedule adherence, and performance. This will enable them to make data-driven decisions, such as adjusting schedules or reallocating buses to meet demand. The system will also provide historical data analysis, allowing for better long-term planning and optimization of resources. Fleet managers can identify trends, such as peak travel times or frequently congested routes, and take preemptive action to mitigate these issues. Another key feature of the proposed system is real-time communication with passengers. The figure 2 depicts the user interface of a "Real-Time Bus Tracking System" for government buses. It shows a simple web-based platform where the user can enter their start and end locations (in this case, Thengaipattanam and Nagercoil). Once the locations are entered, the user can click on the "Navigate to Google Maps" button to get directions.

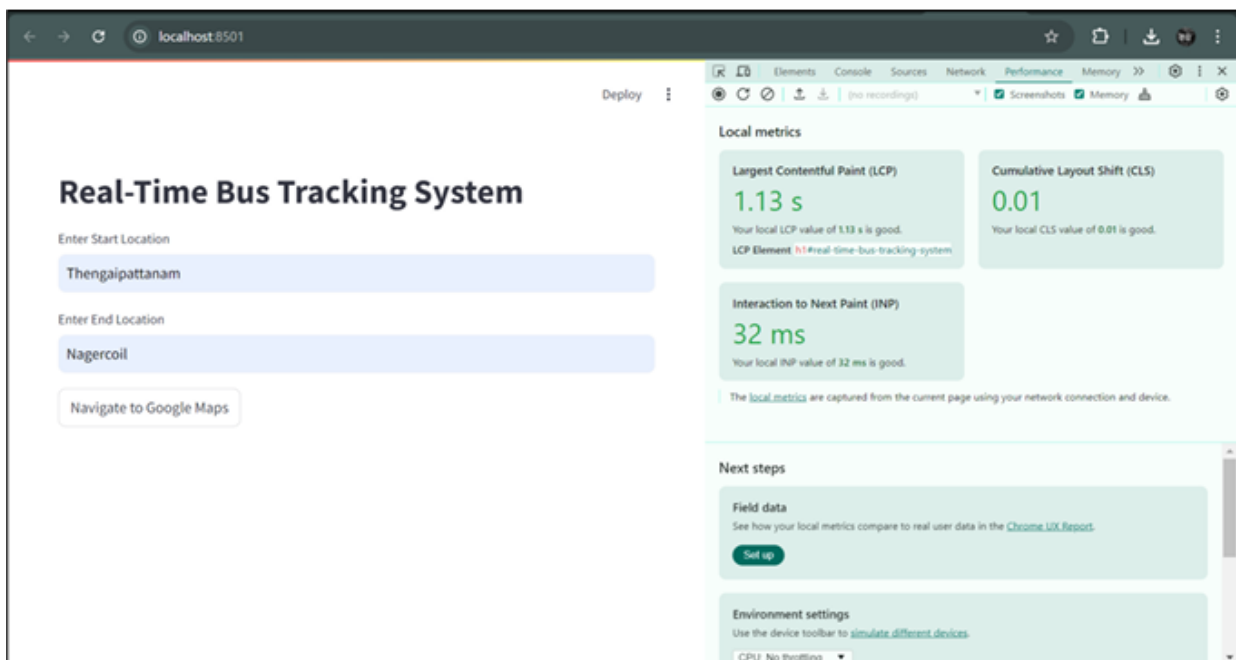


Fig. 2. Real-time Bus Tracking System

Through mobile apps and web platforms, passengers will receive live updates about their bus's status. They can also plan their routes more efficiently by receiving recommendations based on real-time traffic and bus locations.

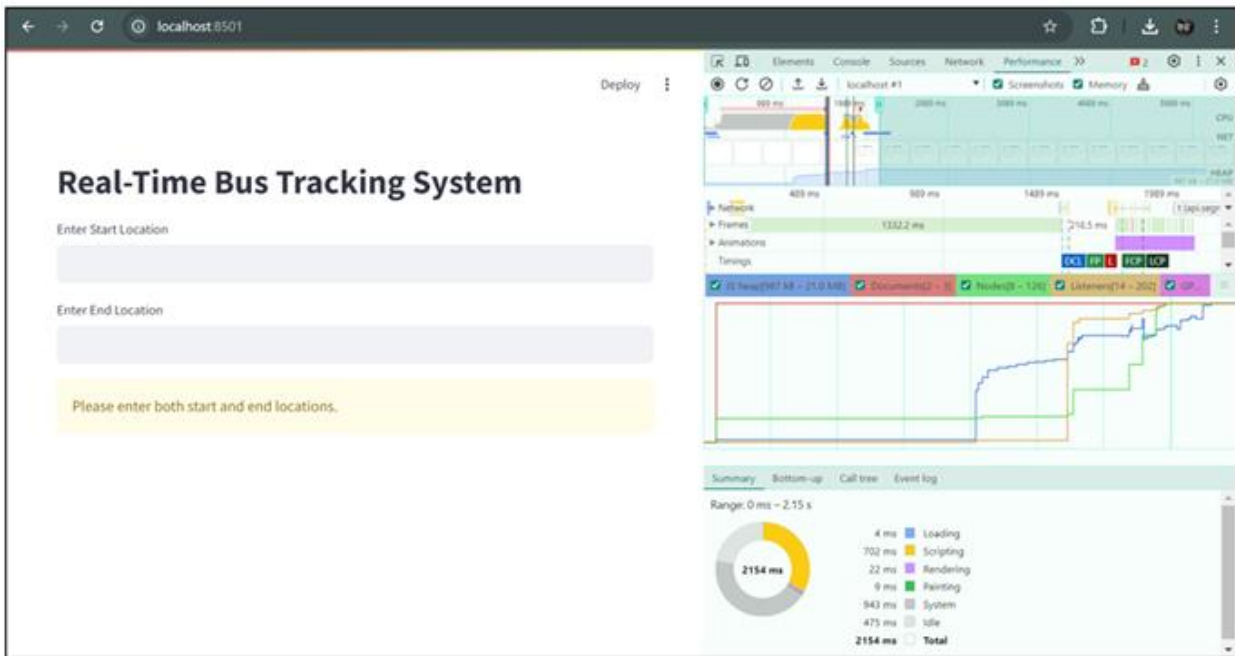


Fig. 3. User Interface (UI) of a Real-Time Bus Tracking System

The figure 3 shows the user interface (UI) of a Real-Time Bus Tracking System. It is developed with Streamlit, an open-source framework for building interactive applications. The UI includes two input fields for users to enter the starting and ending locations for bus tracking. A message is displayed indicating that both locations must be provided before proceeding with the tracking.

In addition, notifications can be sent to alert passengers of disruptions, route changes, or bus cancellations, giving them ample time to adjust their plans. The proposed system also has the potential to integrate modern fare collection methods, such as contactless payments or mobile ticketing. This will not only speed up the boarding process but also enable authorities to track passenger flow in real time, leading to more informed decisions on resource allocation.

4. Conclusion

The proposed work with the integration of GPS, cloud computing, and real-time data processing has proven to streamline bus operations, reduce waiting times, and improve passenger experiences. By providing live location updates, users are empowered with better journey planning capabilities, reducing uncertainties in their commutes. Additionally, the system addresses operational inefficiencies by enabling better route management and facilitating data-driven decision-making for transportation authorities. While the system demonstrates a clear potential to enhance public transportation efficiency, its successful implementation requires overcoming challenges such as infrastructure limitations, data

security concerns, and accessibility for users with limited digital literacy. The study advocates for further development and adoption of real-time tracking systems, proposing that such advancements could lead to more sustainable, reliable, and user-friendly public transportation networks. The insights shared in this paper serve as a guide for stakeholders aiming to modernize transit systems, offering a scalable model that can inspire similar innovations globally.

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Green Campus Initiatives at Holy Cross College: Advancing the SDGs through Sustainable Practices – A Case Study

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ABSTRACT

This paper examines the Green Campus Initiatives at Holy Cross College (HCC), highlighting how the institution integrates sustainability into its operations and aligns its efforts with the United Nations Sustainable Development Goals (SDGs). The study explores a range of sustainable practices implemented on campus, including energy conservation, waste management, water sustainability, biodiversity preservation, and awareness campaigns aimed at fostering an environmentally responsible culture.

By adopting a holistic approach to sustainability, Holy Cross College not only enhances its ecological footprint but also promotes SDG-oriented education and community engagement. This research provides insights into the challenges and opportunities associated with implementing green practices in higher education settings. It also underscores the critical role of such initiatives in equipping students, faculty, and staff with the knowledge and skills necessary to address global environmental challenges. The findings from this case study aim to inspire other institutions to adopt similar strategies, contributing to a collective global effort toward sustainable development.

Keywords: Green Campus, Green Initiatives, Higher Education Institutions, SDGs, Sustainability

Introduction

Sustainability has become a cornerstone of global development, with educational institutions playing a pivotal role in promoting environmental stewardship and achieving the United Nations Sustainable Development Goals (SDGs). Campuses are uniquely positioned to serve as living laboratories for sustainable practices, offering opportunities to implement, study, and refine approaches that address pressing environmental and social challenges.

Holy Cross College has embraced this responsibility by implementing comprehensive Green Campus Initiatives aimed at integrating sustainability into its institutional framework. These initiatives seek to align the college's operations, infrastructure, and community engagement with the principles of environmental responsibility and social equity. Through efforts such as renewable energy use, waste reduction, water conservation, biodiversity preservation, and environmental education, Holy Cross College strives to minimize its ecological footprint while empowering students and faculty to become agents of sustainable change.

This case study examines how the college's sustainable practices contribute to advancing specific SDGs, particularly those related to clean energy, responsible consumption, climate action, and quality education. By documenting the strategies, challenges, and successes of Holy Cross College's Green Campus Initiatives, this research highlights the transformative potential of higher education institutions in fostering sustainability. It aims to inspire similar actions in academic communities worldwide, demonstrating how localized efforts can drive global impact in pursuit of a more sustainable future.

Need for the Study

The urgency of addressing global environmental challenges, such as climate change, biodiversity loss, and resource depletion, necessitates actionable solutions that can be implemented at all levels of society. Educational institutions, as hubs of innovation and knowledge dissemination, are uniquely positioned to lead by example in advancing sustainability. By integrating green practices into their operations and promoting environmental awareness, campuses can significantly contribute to the United Nations Sustainable Development Goals (SDGs) while shaping environmentally conscious global citizens.

Despite the growing emphasis on sustainability, there is a lack of comprehensive case studies that document the practical implementation of green campus initiatives and their alignment with the SDGs. Holy Cross College, with its proactive approach to sustainable practices, offers a valuable opportunity to analyze and share best practices that can serve as a model for other institutions. This study is needed to:

1. **Demonstrate Impact:** Evaluate how the college's initiatives contribute to specific SDGs, such as clean energy, responsible consumption, and climate action.
2. **Bridge Knowledge Gaps:** Provide actionable insights into the challenges, strategies, and outcomes of implementing sustainable practices in higher education.
3. **Inspire Replication:** Encourage other institutions to adopt similar strategies by showcasing the feasibility and benefits of green campus initiatives.

4. **Foster Policy Development:** Inform policymakers and educational leaders about the potential of integrating sustainability into institutional operations and curricula.

By addressing these objectives, this study highlights the transformative role of educational institutions in creating a sustainable future, reinforcing the need for collective action to achieve global environmental goals.

Related Works

The concept of green campuses has garnered significant attention in recent years, as educational institutions increasingly recognize their role in advancing environmental sustainability and contributing to the United Nations Sustainable Development Goals (SDGs). A review of existing literature provides insights into the theoretical frameworks, practical implementations, and outcomes of green campus initiatives across the globe.

Studies highlight the critical role of higher education institutions in promoting sustainability. The article [1] emphasises that universities serve as "living laboratories" for testing sustainable practices, fostering environmental consciousness among students, and contributing to community-wide sustainability efforts. [2] argue that sustainable campus initiatives are essential for reducing institutional ecological footprints while preparing future leaders to address global environmental challenges.

Literature underscores the alignment of green campus initiatives with specific SDGs, particularly SDG 7 (Affordable and Clean Energy), SDG 12 (Responsible Consumption and Production), and SDG 13 (Climate Action). For instance, [3] document the integration of SDGs into higher education institutions' curricula and operational strategies, highlighting the importance of linking campus sustainability efforts with global goals to achieve measurable impacts. Educational programs and awareness campaigns are critical to the success of green campus initiatives. [4] emphasises the importance of sustainability education in equipping students with the knowledge and skills to address environmental issues, both on campus and beyond.

Case studies [5-10] from institutions such as the University of California, Berkeley, and the Indian Institute of Technology (IIT) Delhi demonstrate the impact of innovative green campus strategies on achieving sustainability goals. These examples provide a framework for replicating successful practices in other settings.

Despite their potential, green campus initiatives face challenges, including limited funding, lack of stakeholder engagement, and resistance to change. The discussions paper [11] identifies the need for strong leadership, cross-departmental collaboration, and community buy-in to overcome these barriers.

While the literature provides valuable insights, there is a dearth of comprehensive case studies on sustainability practices in smaller institutions, particularly in developing countries. This highlights the need to document and analyze localized efforts, such as those at Holy Cross College, to provide diverse perspectives on achieving sustainability in higher education.

This review of related works in literature establishes the foundational understanding of green campus initiatives and highlights the relevance of studying Holy Cross College's efforts to advance the SDGs through sustainable practices. It bridges existing knowledge gaps and sets the stage for the detailed exploration of this case study.

Key Areas of Green Campus Initiatives of HCC

Holy Cross College promotes a clean and sustainable campus by motivating students and staff to engage in eco-friendly initiatives, aiming to create environmental awareness and contribute to the protection of the planet locally and globally.

The institution is committed to developing eco-conscious professionals. Courses such as Eco Literature, Green Studies, Environmental Science, Biotechnology, and Nanoscience highlight the importance of preserving the Earth. Students are equipped through field projects, visits, exhibitions, workshops, and seminars focused on environmental conservation and sustainable practices. Initiatives like seed ball distribution and cleaning water bodies (riverbanks and seashores) help transform students into environmentally aware citizens.

1. Energy Efficiency and Renewable Energy:

Numerous studies, such as those by [12], advocate for the adoption of renewable energy sources and energy-efficient infrastructure as a critical component of green campuses. Such practices significantly reduce carbon emissions and promote sustainable energy use [13,14]. The Holy Cross College encourages the usage of public transit among students and its staff. In order to reduce air pollution and carbon foot prints, the college practices “Shuttle Free Day” once a semester and restricts automobile entry on campus to promote the use of bicycles and e-vehicles. Carpooling and Shuttle-Free Day are implemented to reduce the carbon footprint, accounting for approximately 0.52% (582.24 kg CO₂) of the total greenhouse gas emissions.

The institution advocates transitioning to clean and green energy sources, such as solar power, to reduce reliance on non-renewable resources. As part of this effort, the Department of Physics, which has high energy requirements for laboratory purposes, is now fully solar-powered. The college is also committed to reducing energy consumption by

implementing sensor-based smart appliances and energy-efficient devices to minimize waste and improve efficiency.

2. Biodiversity Preservation:

Efforts to enhance biodiversity through tree planting, habitat creation, and green spaces are emphasized in studies like that of [15], which link these initiatives to improved campus aesthetics and ecological health. A Miyawaki forest has been established to promote biodiversity and ecological balance. The college also has a plant tissue culture unit dedicated to the cultivation and propagation of endangered plant species. The HCC actively promotes biodiversity by planting and maintaining medicinal, ornamental, and wild plants across its campus, which hosts over 100 species of Arthropods and rare birds. QR codes are placed to provide information and identification of species. With two-thirds of its 20-acre area covered in greenery, the campus enhances air quality, supports groundwater recharge, and maintains a healthy ecosystem. Tree-planting drives are regularly organized by NSS, NCC, and various departments, including Botany, Zoology, and the Eco-Club at HCC. A herbal garden and vermi-compost unit are also maintained, reflecting the college's commitment to environmental sustainability. Annual events like "International Plantation Day" and "World Environmental Day" further engage students in eco-friendly activities.

The college conducts a Green Audit and holds ISO certification to ensure compliance with sustainability standards, aiming to be a model for sustainable development without additional construction. The campus is home to a rich variety of flora and fauna, which are documented in publications, with students actively involved in data collection to raise awareness and understanding of biodiversity. The institution was awarded the INDIAN World Record for the longest human chain formed to promote environmental awareness. Additionally, green gifts are distributed to guests and resource persons.

3. Water Conservation:

Initiatives such as rainwater harvesting and water-efficient landscaping are widely discussed in the work of [16] for their role in addressing water scarcity and promoting sustainability. HCC employs rainwater harvesting to replenish and recharge groundwater levels, recognizing the value of every drop of water. To support this initiative, multiple pits have been created for collecting and storing rainwater. Rooftops are meticulously maintained to prevent debris from contaminating the rainwater as it flows into the wells.

4. Waste Management:

Research explores waste reduction strategies [17], including recycling programs and composting, as effective tools for minimizing waste generation on campuses.

The Holy Cross College follows the 3Rs - Reduce, Reuse, and Recycle, to promote sustainability. Paper waste generated on campus is collected, segregated, and recycled. Initiatives are undertaken to raise awareness among students on reducing packaged food consumption, reusing and recycling non-biodegradable items, and organizing workshops on solid waste management. As part of the Swachh Bharat mission, solid waste is categorized into biodegradable and non-biodegradable before being handed over to the Municipal Corporation. Dustbins are placed in all departments and classrooms to facilitate the segregation of dry and moist waste, ensuring a clean and eco-friendly campus environment.

The Department of Zoology operates a vermicomposting unit managed actively by students. Organic waste collected from the college grounds is deposited into a designated vermicompost tank. Vermin beds are prepared using a mix of broken bricks, coconut husks, dried leaves, organic waste, cow dung, and earthworms. Students collaboratively install the mixture in the tank and ensure proper irrigation. After eight weeks, the first batch of pure, odorless, granular vermicompost is produced. Students receive technical support for large-scale production. Excess water from the tank is collected as vermiwash, which can also be used as an effective natural fertilizer.

The vermicompost produced by the Department of Zoology is utilized as fertilizer for plants on the college campus, enriching the soil with nutrients and enhancing its fertility. This eco-friendly practice supports soil health without relying on chemical inputs. Additionally, the college has implemented an oxidation pond, which is located near the nursery garden. This pond is equipped with phyto-remediating plants, which help filter and treat wastewater from the hostel. These plants absorb and break down contaminants, purifying the water and making it safer for the environment. This process supports sustainable water management on campus.

Since its inception, the college has taken significant steps in managing solid waste responsibly. Committed to becoming a "Plastic-Free Campus," the college strictly prohibits the use of single-use plastics, aligning with the Government's mandate to ban them due to their adverse effects. To reduce plastic bag usage, the "Manjappai – A Fabric Bag" initiative has been introduced, with awareness campaigns encouraging students and stakeholders to switch to cloth bags. The Department of Zoology and the Eco Club collect used plastic pens from classrooms and departments, ensuring their safe disposal through the Municipal Corporation. Additionally, all departments actively promote the use of fabric bags as part of conference kits during seminars and events.

Awareness programs on e-waste reduction and eco-friendly disposal methods are regularly conducted. The institution ensures proper disposal of waste, with e-waste sent to recycling shops. E-waste management is handled effectively at both departmental and institutional levels. Faulty computers, printers, and other equipment are disposed of as scrap, while printer cartridges are replaced, and UPS batteries are recharged. Adequate funds are allocated for system modernization to support these initiatives.

Findings out of the Study

The study on Green Campus Initiatives at Holy Cross College revealed several key insights into the college's efforts to advance the Sustainable Development Goals (SDGs) through sustainable practices. These findings underscore the institution's commitment to environmental stewardship and highlight areas for improvement to enhance the effectiveness of its initiatives.

1. Implementation of Sustainable Practices

Energy Efficiency: Holy Cross College has adopted energy-efficient practices, including the installation of solar panels and energy-saving appliances, reducing its dependence on non-renewable energy sources.

Waste Management: The college has established a comprehensive waste segregation and recycling program, minimizing landfill contributions and promoting a circular economy.

Water Conservation: Rainwater harvesting systems and efficient water use practices has been implemented, significantly reducing water consumption.

2. Alignment with SDGs

The college's initiatives align with multiple SDGs, including:

SDG 7 (Affordable and Clean Energy):

Through the use of renewable energy sources by installation of solar panels.

SDG 11 (Sustainable Cities and Communities):

Carpooling and Shuttle-Free Day are observed to reduce carbon footprint.

SDG 12 (Responsible Consumption and Production):

By adopting sustainable waste management and consumption practices like use of Manjapai-a cloth bag.

SDG 13 (Climate Action) and SDG 14 (Life Below Water):

The Holy Cross College in association with Pro-Vision (NGO) organized cleaning and awareness campaign to sensitize students and the community on sustainable practices and climate change mitigation.





SDG 15 (Life on Land): Use of biodegradable cotton cloth bags inside campus.




SDG 17 (Partnership for the Goals):

The initiatives followed in HCC educate the community on sustainable practices that enhance air, soil quality and these efforts collectively contribute to building a more sustainable and environmentally conscious community.

The table 1 gives an overview of the practices the Holy Cross College follows that align with the UN's sustainable development goals.

Table 1. Holy Cross College and its Alignment with SDGs

Sustainable Development Goals (SDGs)	Practices followed in Holy Cross College that aligns with the SDGs
 <p>7 AFFORDABLE AND CLEAN ENERGY</p>	<p>The HCC institution has installed four solar lights in Kattuvillai and Pozhikkarai. The Institution has installed a solar light in Thollavillai.</p>
 <p>11 SUSTAINABLE CITIES AND COMMUNITIES</p>	<p>HCC practice of Carpooling and Shuttle free day enhances air quality (approximately 0.52% (582.24166 kg CO₂) of the total Green House Gas emission).</p>
 <p>12 RESPONSIBLE CONSUMPTION AND PRODUCTION</p>	<p>Adopts sustainable waste management and consumption practices. Sustainable practices of HCC reduce waste generation and promote recycling and reuse.</p>
 <p>13 CLIMATE ACTION</p>	<p>Awareness and Training on Bio-fertilizer- Pipe Composting and Vermi Composting were given to Students and people of Pozhikarai. The institution of Pipe Composting Unit by the institution.</p> <p>In an effort to reduce the institution's carbon footprint students under NSS, RUN and UBA participated in the shoreline cleaning activity at Pallam, Periyakadu, Muttom, Manakudy, Annai Nagar, Colachel, Rajakamangalam, Pozhikarai, Vaniyakudi and Puthenthurai. Plastic wastes collected from the shoreline were dispatched for recycling.</p>

	<p>The Institution's departments of Zoology and Botany observed World River Day and Van Mahotsav, eco-friendly initiatives, to clean riverbanks by eradicating parthenium weeds and other plastic wastes.</p>
	<p>The College initiated Meendum Manjapai (Use of Cloth bags) during 2022-2023. Participated in the INDIAN World Record for the longest human chain to promote the use of Cloth bags. A Manjapai vending machine is installed at the institution. Departments opted for Manjapai instead of plastic files for seminars/conferences. Students distributed cloth bags to the villages they visited for extension services.</p>
	<p>Wellness and Health Camps, Medical and Blood Donation Camps were organised regularly by the RRC, YRC, Rotaract Club and NSS of the institution. The sustainable practices followed by HCC educate the local community and in turn builds an environmentally conscious community.</p>

3. Engagement and Awareness

Community Involvement: Students, faculty, and staff are actively involved in green initiatives through awareness campaigns, workshops, and participation in eco-friendly projects.

Curriculum Integration: Sustainability themes are embedded in the curriculum, fostering an environmental consciousness among students.

Collaborations: Partnerships with local organizations and government bodies have supported the implementation of sustainability projects.

4. Environmental and Social Impact

Biodiversity Conservation: The college has developed green spaces and biodiversity zones, preserving native flora and fauna.

Reduction in Environmental Impact: Significant reductions in energy use, waste production, and water consumption have been observed.

Positive Influence on the Community: The initiatives have inspired neighboring communities to adopt similar practices, amplifying the impact.

5. Challenges Identified

Resource Constraints: Limited funding and technical expertise pose challenges to scaling up sustainability projects.

Behavioral Barriers: Resistance to change among some stakeholders limits the full adoption of sustainable practices.

Monitoring and Evaluation Gaps: The absence of robust mechanisms for tracking the impact of initiatives hinders data-driven decision-making.

6. Recommendations for Improvement

Strengthen stakeholder engagement through enhanced communication and training programs. Explore additional funding opportunities, including grants and corporate sponsorships, for expanding sustainability projects.

Establish monitoring frameworks to measure and evaluate the long-term impact of initiatives. These findings demonstrate Holy Cross College's proactive role in fostering a green campus and advancing the SDGs. With targeted improvements, the college can further enhance its contributions to sustainability and serve as a model for other educational institutions.

Conclusion

The Green Campus Initiatives at Holy Cross College exemplify how educational institutions can play a pivotal role in advancing the United Nations Sustainable Development Goals (SDGs) through the adoption of sustainable practices. By integrating environmentally conscious strategies into campus operations, the college has successfully reduced its ecological footprint while fostering a culture of sustainability among students, faculty, and the broader community.

This case study demonstrates that comprehensive efforts, such as renewable energy use, waste and water management, biodiversity conservation, and sustainability-focused education, can significantly contribute to creating a greener and more sustainable future. While challenges such as resource limitations and stakeholder engagement persist, the innovative approaches and collaborative efforts at Holy Cross College provide a replicable model for other institutions aiming to align with global sustainability goals.

Ultimately, the initiatives underscore the transformative potential of higher education institutions as change agents in addressing environmental challenges, building sustainable communities, and inspiring global action for a better tomorrow.

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Lexicon Based LSTM Framework for Context-Aware Fake News Detection on Social Media Platforms

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ABSTRACT

The rise of fake news in social media platforms threatens information accuracy and public trust. In order to enhance the identification of fake news, this study presents a Lexicon-Based Long Short-Term Memory (LSTM) framework that integrates social context and content analysis. The model uses a lexicon of keywords, sentiment cues, and deceptive language to enhance feature analysis. It also incorporates social context, such as the reliability of sources, user engagement, and how news spreads, to better understand misinformation patterns. The LSTM processes data in sequence to identify patterns in both content and its dissemination. Test on publicly available standard dataset shows that this method outperforms traditional approaches with higher accuracy. Adding lexicon features and social context makes the model better at detecting fake news. This framework offers an effective and scalable way to reduce the spread of misinformation and supports efforts in content moderation and social media regulation.

Keywords: Fake News Detection, Lexicon-Based Approach, Long Short-Term Memory (LSTM), Social Media Platforms

1. Introduction

The rapid rise of social media platforms has completely transformed how information is created, shared, and consumed. While these platforms enable instant communication and global connectivity, they have also transformed into breeding grounds for the spread of fake news. The dissemination of misinformation on social media undermines public trust, influences opinions, and, in extreme cases, leads to significant societal and political consequences. Addressing these challenges requires effective and scalable tools capable of distinguishing between genuine and false information [1]. Traditional models of fake news detection, primarily focused on textual content analysis [2], often overlook the social context in which the news is shared. However, the propagation patterns, user interactions, and

credibility of sources have a critical role in distinguishing authentic news from that of fake news [3]. Additionally, the nuanced use of language in misinformation calls for advanced methods that go beyond basic text processing.

This paper proposes a Lexicon-Based Long Short-Term Memory (LSTM) framework that integrates both the content and the social context for the detection of fake news. The model uses a curated lexicon containing sentiment markers, domain-specific keywords, and deceptive language indicators to enhance the analysis of textual features. Furthermore, the framework incorporates social context factors, such as user engagement metrics, source credibility, and news-sharing patterns, that provides a holistic view of misinformation dynamics.

Long Short-Term Memory (LSTM) networks have demonstrated significant improvements in capturing semantic and temporal dependencies in textual data. However, many of these models focus solely on textual content, overlooking the critical role of social context—such as source credibility, user engagement patterns, and propagation dynamics—in distinguishing fake news from genuine content. To address these limitations, hybrid approaches have emerged. For example, works by [4] [5] have highlighted the importance of incorporating social context into fake news detection models. These studies emphasize that user behavior, source characteristics, and dissemination patterns provide valuable cues for identifying misinformation. Similarly, lexicon-based techniques have been employed to enhance feature extraction by leveraging domain-specific keywords and sentiment markers, as seen in the works of [6].

By combining the sequential processing capabilities of LSTM networks with enriched feature inputs [7] from the lexicon and social context, this framework offers a robust solution to fake news identification on social networking sites. This study demonstrates the efficacy of the proposed framework in identifying fake news with greater accuracy and reliability, contributing initiatives to combat misinformation in this digital age. Through this work, we aim to develop scalable, data-driven solutions to combat misinformation on social networking platforms.

2. Proposed Methodology

The proposed methodology centers around developing a Lexicon based Long Short-Term Memory (LSTM) based model for identifying fake news. The proposed system aims to enhance false news detection by incorporating sentiment analysis into a Long Short-Term Memory (LSTM) model. This system uses sentiment embeddings derived from a sentiment lexicon to improve word representation and overall classification accuracy.

The figure 1 illustrates the fake information detection model using a lexicon based Long Short-Term Memory (LSTM) model. The Fake news Web User Interface is the primary interface module for both system administrators and users. System Administrators can log in to access the training pipeline for detecting fake news. Users can interact with the system to check if a news post is fake or genuine after logging in or registering. Load News Dataset is the module where a system administrator loads a news dataset with labeled data (e.g., fake or genuine news). This data serves as input for the training phase in the fake news detection system model.

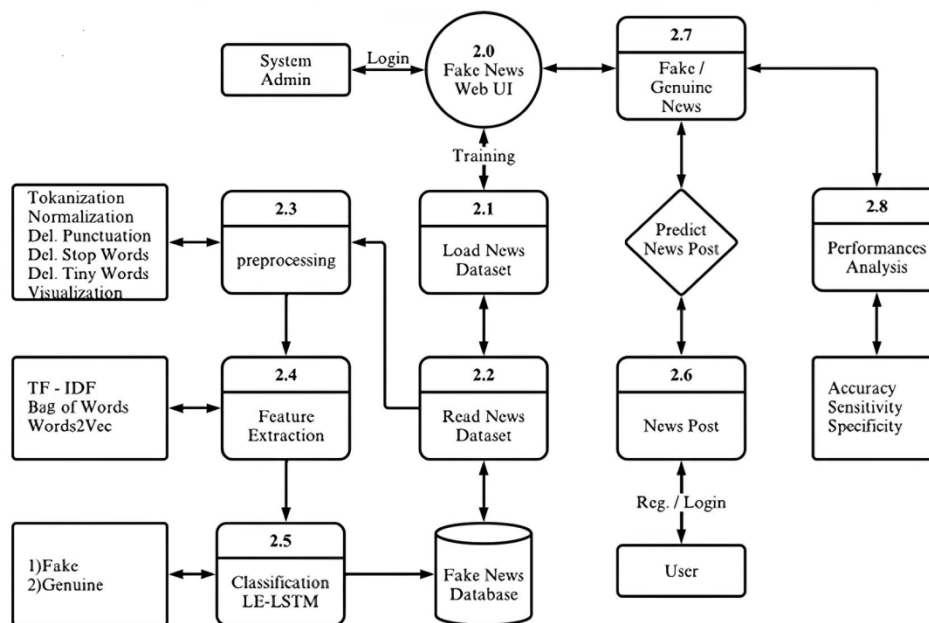


Figure 1. Lexicon Based LSTM Fake News Detection System

The Read News Dataset module processes the uploaded dataset for further analysis. It ensures that the data is correctly formatted for preprocessing and feature extraction. Fake News Database module stores processed news data, training datasets, and the outputs of classifications for reference and improvement of the detection model.

3. Preprocessing Module

In this module, the raw text data is prepared for feature extraction by applying the following:

Tokenization: Breaking of the text into individual words or tokens. **Normalization:** Standardizing text input, such as converting all words to lowercase. **Removal of Punctuation:** Eliminating punctuation marks to focus on meaningful content. **Stop Word Removal:** Removing frequently used words (e.g., "is," "and," "the") that do not add significant meaning. **Removal of Tiny Words:** Eliminating words with very few characters to reduce noise. **Visualization:** Visualizing the data (e.g., word clouds, frequency distribution) for better

understanding.

4. Feature Extraction

Extracts numerical representations of the text data using methods such as: TF-IDF (Term Frequency-Inverse Document Frequency): Measures the importance of a term in a document relative to the dataset. Bag of Words: Represents text data as a collection of word occurrences. Word2Vec: Converts words into continuous vector representations based on their context.

Classification Using Lexicon Based LSTM

This module uses a Lexicon Based Long Short-Term Memory (LE-LSTM) neural network for classification. The Lexicon Enhancement involves adding sentiment analysis or semantic information from a lexicon to improve accuracy. The model through user engagement and keywords incorporates social context along with textual features in its analysis of fake news. The LSTM model processes sequential data to classify news posts as either Fake or Genuine. In module News Post Submission, users submit a news post and the system processes it and predicts whether the post is fake or genuine based on the trained model. In the Prediction Output module, after processing the input, the system outputs the prediction: as Fake News or as Genuine News. Figure 2 shows the output screen when genuine and fake messages are posted.

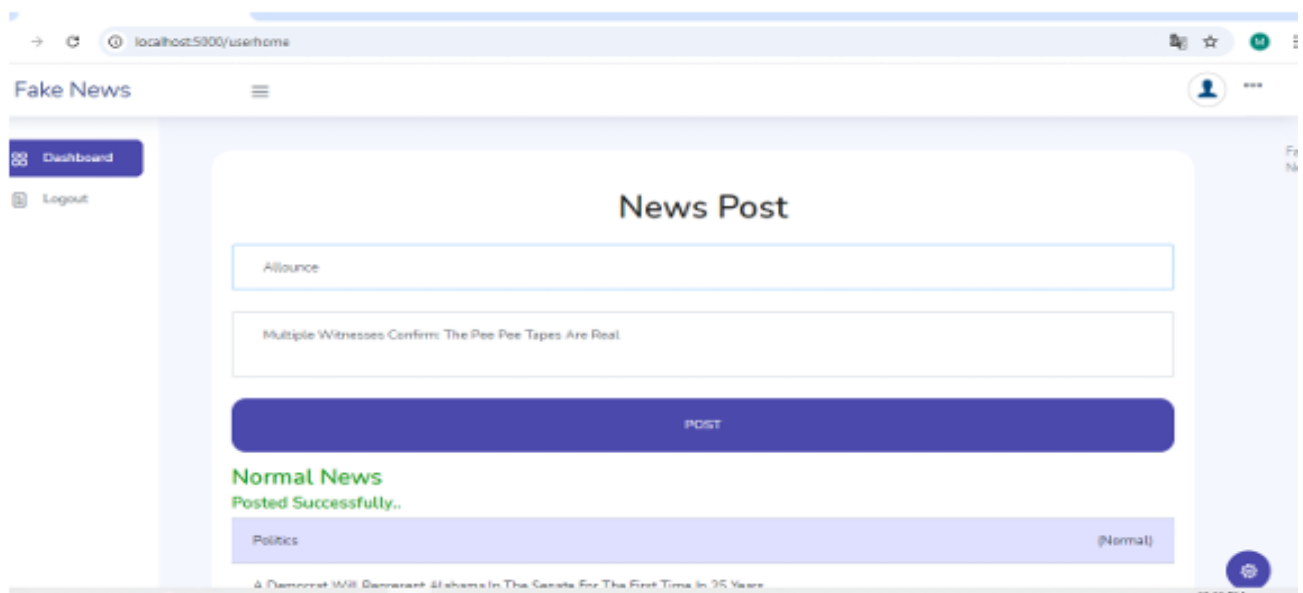


Fig. 2. Output Screen of a Genuine User Post

5. Conclusion

This paper introduces Lexicon-Based LSTM architecture for social media fake news detection. The model combines a lexicon of key phrases and deceptive language with the

power of LSTM networks to analyze both the content and the social context in which news spreads. By considering factors like source credibility, user engagement, and how news is shared, our approach improves the accuracy of false news detection. Through its combination of semantic and contextual features, the proposed model exhibits superior output. Also, the proposed model outperforms traditional methods by better capturing the nuances of both language and social dynamics. This approach offers a scalable solution for applications like content moderation and fact-checking. Future work could expand the model to include other forms of media, like images and videos, and refine the lexicon to stay update with emerging trends in online content.

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Social and Religious Reforms of Ayya Vaikundar: Transforming the Caste System and Uplifting Marginalized Communities in Kanyakumari

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ABSTRACT

Ayya Vaikundar was an influential social and religious leader in the Kanyakumari region. This research paper examines his transformative impact on the lower castes. Born in Thamaraiikulam, a village in Nanchil Nadu, Vaikundar is believed to be an incarnation of Lord Vishnu. His divine transformation led to the founding of Ayyavazhi, a new religion that aimed to uplift marginalized communities and challenge caste-based oppression. Vaikundar's reforms addressed social, religious, and political issues faced by the lower castes, including unfair taxes, untouchability, and limited access to education and religious practices. Through his teachings, Vaikundar advocated for equality and social justice. He introduced several reforms such as Samapanthibhojan (equal dining), Munthirikinaru (a well for all castes), and Thottu Namam Chathuthal (a practice to allow lower castes to enter temples), promoting unity and breaking caste barriers. His call for self-respect led to the abolition of discriminatory practices such as the prohibition on lower castes wearing turbans or participating in religious ceremonies. Vaikundar also emphasized the importance of regional language, preaching in Tamil to ensure his teachings were accessible to all. His efforts led to significant changes, such as the end of animal sacrifices in temples and the introduction of Annadharmam, which provided food to worshippers, addressing both spiritual and material needs. Vaikundar's influence extended beyond religious reform, helping to shape the socio-political landscape of South Travancore, and fostering a sense of dignity and unity among the oppressed. This paper delves into his life and reforms, highlighting his contributions to social equality, religious transformation, and the empowerment of the lower castes.

Keywords: Ayya Vaikundar, Caste System, Ayyavazhi Faith, Religious Reforms, Social Justice, Untouchability, Marginalized Communities

Introduction

Kanyakumari district, which was part of the Travancore state until 1956 [1] has a rich cultural and social history, shaped by the struggles of marginalized communities against oppressive caste systems and discriminatory practices. One of the most influential figures in the region's socio-religious landscape was Ayya Vaikundar, believed to be an incarnation of Lord Vishnu. He led a transformative movement for social reform in the 19th century. Born in

the village of Thamaraiikulam, Vaikundar's life and teachings had a profound impact, particularly on the lower castes in South Travancore. His mission was to uplift the oppressed and challenge the caste-based discrimination that existed at the time.

This paper explores the life, reforms, and legacy of Ayya Vaikundar, focusing on his contributions to the social, religious, and political empowerment of the oppressed. By founding the Ayyavazhi faith and introducing radical changes to religious practices, Vaikundar broke the traditional norms that kept the lower castes marginalized. He enabled them to enjoy equal rights, access to temples, and the ability to live with dignity. His reforms addressed the deeply entrenched casteism of the time, promoting equality, self-respect, and social justice. Besides, Vaikundar's teachings had a lasting impact on religious practices in the region, as he introduced Tamil as the medium for spiritual instruction, making religious rituals and practices accessible to everyone, regardless of caste. It examines the key reforms introduced by Vaikundar, such as Samapanthibhojan (equal dining), Munthirikinaru (a well for all castes), and the elimination of untouchability through his religious actions. His teachings and practices, which challenged both religious and social norms, have had a lasting influence and continue to resonate today [2]. By analyzing Vaikundar's role in shaping the social fabric of Kanyakumari district, this research highlights his significant contributions to the broader movements for social justice and religious reform in India.

His Early Days

A hardworking and poor couple, Ponnu Nadar and Veiyelal, lived in a hut in the Palmyra and coconut grove owned by a landlord. In 1809, they were blessed with a baby boy. They named him Mudisoodum Perumal, meaning "the Lord with a crown" [3]. However, the name faced opposition, and the parents were forced to change it. They renamed him Muthukutty. Muthukutty grew up helping his parents. Eventually, he got married and lived a happy life. He had a son named Podhukutty. At the age of 22, Muthukutty fell ill with an incurable disease and was bedridden for a year. One night, his mother prayed earnestly to Lord Vishnu for her son's recovery before falling asleep. In her dream, Lord Vishnu appeared and instructed her to take Muthukutty to Tiruchendur for the Masi Festival. He promised that Muthukutty would recover and lead a holy life. The next morning, she shared the dream with her relatives, and they decided to take him to Tiruchendur [4].

At that time, there were no motor vehicles, and the family could not afford a bullock cart. Since Muthukutty was too weak to walk, they decided to carry him in a cloth cradle. Early one morning, they began their journey to Tiruchendur. By midday, they reached a river called Thottavazhi Aru. After having their meals, they rested for a while. To everyone's

surprise, Muthukutty, who could not walk even a step before, suddenly got out of the cradle and ran toward Tiruchendur. Everyone followed him in astonishment [5].

Incarnation as Lord Vishnu

At Thiruchendur, he walked through the four streets, surprising his followers who watched him in awe. Then, he walked into the sea and disappeared. His followers searched for him for two days but could not find him. Although they tried to comfort his mother, she remained unconvinced and believed her son would return. She waited by the seashore for three days. On the third day, March 3, 1833 (Twentieth of Masi, Kollam Era 1008), he emerged from the sea. When his mother saw him, she ran to embrace him, but he stopped her, saying he was no longer her son. He declared himself as Vaikundar, an incarnation of Lord Vishnu. He explained that in the sea, Lord Vishnu had transformed him into Vaikundar and given him divine instructions (Vinchais). Lord Vishnu commanded him to go to Swamithoppu, perform penance for six years, and establish a new religion. Obeying this, he left Thiruchendur on foot and reached Swamithoppu, a holy village. From there, he performed many miracles, which drew people to him. They called him "Ayya Vaikundar," and he went on to found the new religion known as "Ayyavazhi" [6].

Society in Travancore

In the early 19th century, the princely state of Travancore was ruled by kings with the support of the East India Company. During this time, the Diwans, who were the executive heads of the state, worked hard to ensure the English received their share of income from the state. The king had to pay a large amount to the East India Company to maintain the English Residential Force stationed in Travancore. As a result, heavy taxes were imposed on the lower castes such as Nadars, Shanars, and Ezhavas. Further, caste discrimination was strictly practiced during this period. The lower castes, referred to as avarnas, were treated as untouchables and faced severe punishments. The rulers favored the upper castes, including Nambudiris, Nairs, and Vellalas, while the lower castes suffered greatly. They were not allowed to enter temples and were subjected to numerous restrictions, making their lives extremely difficult [7].

Reforms of Ayya Vaikundar

In this situation, Vaikundar worked to uplift the poor and downtrodden lower castes of South Travancore. His goal was to improve their living standards and bring them on par with the privileged castes. His mission aimed at bringing about social, cultural, and religious reform among the people. To achieve this, he became involved in politics to protect the lower castes from the severe atrocities committed against them by the ruling king of Travancore [8].

Samapanthibhojan

Untouchability is a social evil that has almost disappeared today. However, in the past, it created a distorted mindset in society. This harmful practice, deeply rooted in casteism, led to many atrocities against the downtrodden. The lower castes were labeled as untouchables, their presence was despised, and they were even forbidden from entering temples. Vaikundar aimed to eliminate this practice from society. He organized Samapanthibhojan (equal dining) in every place of worship under the concept of Annadharmam. People, regardless of their caste, sat together and shared meals prepared in the temples. At that time, it was unthinkable for people to eat food cooked by the lower castes. Vaikundar sent his disciples to different villages, encouraging them to share meals with the lower castes to break the barriers of untouchability [9].

Munthiri Kinaru

In those days, casteism was so rigid that each caste had its own separate well, and people from other castes were not allowed to draw water from it. To eliminate this caste-based discrimination, Vaikundar established a well called Munthiri Kinaru. This was the first well in the region where people from all castes could come together and use the water. Through this initiative, he helped liberate the lower castes from the grip of casteism [10].

Thottu Namam Chathuthal

In those days, the lower castes were not allowed to enter even the temple premises. In response, Vaikundar introduced a significant practice called Thottu Namam Chathuthal. This involved applying a sacred Namam on the foreheads of low-caste devotees in the shape of a Jyothi. Unlike the traditional practice of temple priests throwing sacred ash or sandal paste at devotees, Vaikundar applied it reverently himself. Through this act, he opened the way for the lower castes to enter temples and participate in worship [11].

Democratic Siddhantha

In those days, the lower castes in Travancore were not allowed to wear turbans or dress like the higher castes. Vaikundar sought to eliminate this discrimination and promote self-respect among the lower castes. He encouraged those who came to him to wear turbans and dhotis that reached down to their toes. By doing this, he practiced and upheld the principle of equality, bringing dignity and unity between the downtrodden and the upper castes.

Thuvayal Panthy

Before establishing the new religion Ayyavazhi, Vaikundar wanted to train the lower castes and those willing to join this new faith, similar to how governments and organizations

provide training before launching a project. His unique method of training was called Thuvayal Panthy, which means integration and purification of a group. Vaikundar aimed to bring social reform among the lower castes, as cleanliness was often neglected in those days. Through Thuvayal Panthy, he instilled habits of discipline, such as bathing daily, washing clothes three times a day, and maintaining overall cleanliness. This initiative not only improved their hygiene but also freed them from dirt and disease, uplifting their lives significantly [12].

Anbu Kodi and Love

Vaikundar wanted to establish a new religion and designed a flag to represent it. This flag, known as Anbukodi, means "Love." It is saffron in color with a single Namam in the shape of a Jyothi in white on both sides. He taught the lower castes that love was the key to uniting society and fostering better development. Through his teachings, he encouraged them to love and support one another, leading meaningful lives by helping each other. As a result, the lower castes developed a deep faith and devotion to their Lord [13].

Nizhal Thangal as Basic Schools

Vaikundar established temples called Nizhal Thangals to bring people together and spread his teachings to the masses. These Nizhal Thangals attracted many followers and became the primary centers for learning about his teachings. In some villages, they also served as basic schools, providing education to the community. Through these efforts, Vaikundar played a significant role in the socio-religious revolution [14].

Pari Tax

In those days, the lower castes had to pay heavy penalty taxes, and the higher castes imposed additional taxes on them in the name of Pari. The lower castes were also forced to work for the state without wages. Vaikundar appealed to the king to stop collecting these penalty taxes and other charges, but the king refused his request. In response, Vaikundar urged the lower castes, especially the Nadars, to refuse to pay the penalty taxes and other fees, and not to work without wages. They followed Vaikundar's advice and disobeyed the king's orders. As a result, the king was forced to cancel all the taxes and the requirement for unpaid labor.

Regional Language in religion

During that time, the Hindu religion was controlled by the Brahmins. They performed daily rituals in temples using Sanskrit, and even marriages were conducted with mantras in Sanskrit. Sanskrit was dominant in Hinduism, and the Brahmins considered it the language of the gods, forbidding other castes from learning it. However, Vaikundar strongly opposed this

practice. He preached in Tamil, the regional language, so everyone could understand. At that time, the temples were managed by kings and their supporters. The religious texts, like the Vedas and Upanishads, were mostly in Sanskrit. The Upanishads contained little information about individuals, while the Vedas focused mainly on philosophy. The Puranas, which were also important, came after the Vedas and Upanishads. Since these texts were in Sanskrit, the lower castes could not learn them or follow the teachings. Vaikundar, however, wrote his own books in Tamil to make them accessible to all [13].

Unique Marriage Ritual

Vaikundar created a unique marriage ritual that is conducted in the regional language, Tamil. He described this marriage as the marriage of Lord Kantha, with Lord Shiva acting as the guru, and the ceremony taking place in the presence of Lord Vishnu. In this ritual, the bride and groom sit facing south, and an elderly man from the village, who serves as the guru, performs the marriage rites. Through this, Vaikundar introduced reforms to marriage, eliminating the need for Brahmins and Sanskrit. He also used Tamil in the Nizhal Thangals to ensure that everyone, including common people, could understand the teachings and follow proper behavior [6].

Simplifying the religions

Vaikundar wanted to make his religion accessible to the common people, so he decided to simplify it. He built small structures called Nizhal Thangals, where worship was kept simple. There were no idols, no priests, no rituals like poojas, no camphor, no incense, and no donation boxes. People could worship in their own way and at their own convenience. Anyone, regardless of caste or creed, could perform panividai, which means decorating the sanctum sanctorum of the Nizhal Thangal [15].

Annadharman

Every religion has its own objectives, but in general, all religions guide people on the right path. However, despite this, many atrocities are committed in the name of religion. Vaikundar believed that people who came to places of worship should be provided with food after praying. He thought that only when people's hunger was satisfied would they be able to focus on God and righteousness. To address this, he started Annadharman in places of worship and worked to eliminate the wrongs done in the name of religion [16].

Preaching against Animal Sacrifice

Today, social organizations condemn the practice of animal sacrifice in temples. However, Vaikundar spoke out against this practice 150 years ago. At that time, people

sacrificed animals in temples as an offering to God. Vaikundar preached against this practice and put an end to it [17].

Conclusion

Ayya Vaikundar's life and reforms represent a significant turning point in the social, religious, and political history of the Kanyakumari region, particularly for the lower castes. His teachings and practices not only challenged the deeply entrenched caste discrimination but also promoted a vision of equality, unity, and social justice. Vaikundar's creation of the Ayyavazhi faith and his emphasis on regional language, Tamil, in religious practices made his teachings accessible to a broader section of society, ensuring that the marginalized could participate fully in spiritual and social life. His innovative reforms, such as Samapanthibhojan, the establishment of Munthirikinaru, and Thottu Namam Chathuthal, served as direct responses to the rigid caste system and oppressive social norms of the time. By advocating for practices like the equal sharing of food and allowing all castes to access public resources like wells and temples, Vaikundar laid the groundwork for a more inclusive society. Additionally, his efforts to combat social evils such as untouchability and the discriminatory practices enforced by the ruling elite reflected his deep commitment to justice and human dignity.

Vaikundar's advocacy against animal sacrifice, his focus on simplifying religious rituals, and his encouragement of self-respect among the lower castes through democratic principles like the wearing of turbans were instrumental in transforming not only the religious landscape but also the socio-political fabric of South Travancore. His teachings empowered the oppressed, gave them a voice, and restored their sense of identity and self-worth. Ultimately, Ayya Vaikundar's contributions to social reform were not merely a reaction to the injustices of his time but a forward-thinking vision of a society where every individual, regardless of caste, could live with dignity and equality. His legacy continues to inspire and influence movements for social justice and religious reform in contemporary times, making his work an important milestone in the history of social change in India.

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The Gandhian Strategy to the Socio-Economic Problem

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ABSTRACT

Gandhiji strongly opposed industrialization, urbanization, large-scale industry, and the use of machines. Gandhiji's ambition was a small, independent village republic comprising agriculture and a few minor industries. He was a strong supporter of manual labor. He asserts that everyone needs to work physically in order to support themselves. No worker is inferior to the other worker. Whether one does mental or manual work, it is the same and the wages must be equal. As long as any commodity could be produced by human hand, machines should not be used. Industrialism leads to overproduction, which in turn leads to a search for markets and imperialism. He wanted every village to be self-sufficient. Gandhian economics or the Gandhian strategy to the socio economic problem is determined by his vision of man. Insofar as man is by nature a moral, spiritual and religious being, Gandhian economics is also deeply rooted in morality and spirituality. The moral and spiritual nature of man means that man is more than a living body and its needs or urges; that his character, history and destiny are shaped by his attitude and behaviour, even in economic activities towards God and the universe. Gandhi believed that our issue goes beyond economics. It's more of a problem with the entire man. The economic man's abstraction was not created by Gandhi. He encouraged everyone to examine human nature holistically, but especially economists.

Keywords: *Gandhian economics, Self-sufficiency, Mechanisation, Individual labour*

Introduction

Gandhian economics is an economics of the spirit- an economics whose criteria arise outside the exclusively economic sphere. In other words, the criteria of Gandhian economics are spiritual and are integrally and socially human. According to these criteria not every quantitative increase would represent progress. The reason is that progress is fundamentally qualitative and must always be evaluated by its overall impact on human life, even when it is tied to quantity. Progress in other words is social and spiritual and not merely materialistic. One may even go further and say that progress consists often in ascendancy over matter and is independent of it; it depends wholly on man as spirit, consisting in the mastery of the spirit over matter. That is why renunciation of material goods represents a measure or step in

progress strictly so called. Gandhian economics is built on an ascetical concept and ideal of progress, namely renunciation; it is a perfect blend of economics and spirituality.

Methodology

The methodology adopted for this article is primarily qualitative, focusing on interpretive analysis of primary and secondary texts related to Gandhian economics. The study involves examining Gandhi's writings, speeches, and historical accounts to capture his philosophical outlook on socio-economic issues, especially as articulated in his texts, such as *Harijan* and *Young India*. The analysis seeks to contextualize Gandhi's ideas within both his own cultural and philosophical influences, like the Bhagavad Gita and Indian spiritual tradition, and Western thinkers such as Tolstoy, Ruskin, and Bondareff.

Using a hermeneutic approach, the article interprets Gandhian economics as a moral and spiritual paradigm that challenges modern capitalist and materialist frameworks. This methodology emphasizes understanding the core principles behind Gandhi's ideas on self-sufficiency, the rejection of excessive mechanization, and the prioritization of community welfare over individual profit. A comparative textual analysis also highlights Gandhi's critiques of capitalism and socialism, positioning Gandhian economics as a distinct model rooted in non-violence and social harmony.

Gandhian Economics

Gandhian economics is structurally socialistic as opposed to laissez-faire or individualistic. Instead of considering the individual social unit, the economic good is understood in terms of the entire society. And the economic good is determined by society, not by the individual. Human society is geographically organized from the family into the village, district, province, and nation. They are all components of the global society. Each unit must continue to be open to all others, particularly the larger unit, in order to determine the economic good. Therefore, economic activity must, from its abundance, meet the requirements of at least its immediate neighbor, even though its primary goal is to meet the needs of the local or regional society.

Concretely speaking, the family must serve the village, which in turn must serve the district, which in turn must serve the nation, which in turn should serve the world. Each unit's economy would only be one of sufficiency and not superfluities when it attempted to meet both its own and its neighbors' requirements. Because the neighboring unit cannot afford to stockpile and enjoy superfluities when the last or least member of society is struggling to meet basic needs [1].

To quote Gandhi, "The whole gamut of man's activities today constitutes an indivisible whole. You cannot divide social, economic, political and purely religious work into water tight compartments. I do not know any religion apart from human activity. It provides a moral basis to all other activities which they would otherwise lack, reducing life to a maze of sound and fury signifying nothing" [2].

Gandhi's economy would also be stable because essentials are probably going to stay the same. When an economy is focused on the many superfluities or luxuries rather than the few basics, it becomes unstable and prone to inflation. Regardless of the mechanism of supply and demand, prices would be constant and not rising in a stable economy since there would be less incentive to take advantage of or deprive others in order to further one's own interests. In other words, the service motive would rule over the exploiting, profiteering motive. The Profit motive generates an economy of its own kind. In it, money and matter take precedence over man, and the true scale of values is perverted. In the service- motivated Gandhian economics, man is to rule over money, goods and economy. He is to judge the existing economy and work for the kind of economy needed from time to time rather than allow any one economy or structure to dominate over him, or impose itself on him. A self-generating economy gives man no freedom of choice over it. The Gandhian is a charismatic economy where every economic structure or arrangement can be reassessed and adapted either periodically or whenever the need arises [3].

Self-sufficiency

As the economics of sufficiency and self-sufficiency, the Gandhian self-sufficiency economy needs to be structurally small and simple. It would be a system of life where people find sufficiency in a few things like food, clothes, shelter, health and education. Qualitative differences in them are not ruled out. Only the selection of one grade rather than another would be guided by consideration for the last, the least and the weakest member in the economic community. Equality and community or fraternity are and therefore for greater values in the Gandhian mind than possessions their enjoyment. Self-sufficiency means self-support and non-dependence on foreign or distant parts for essential goods. Hence, where nature does not prevent it, every part should ordinarily produce the essential goods it needs. Gandhi advocates independence of foreign lands for essential goods, because dependence, when not mutual, is a condition favourable to exploitation and inequality and as is a distortion and negation of true values. However, nondependent and self-support do not mean callous refusal to help the neighbouring or foreign country when it is rendered unable to support itself. This is the right place for cooperation. Gandhi envisages a small and simply structured

economy, because with growth in size the exploitative tendencies also increase and manifest themselves in lazy dependence on the one hand and exorbitant profit on the other [4].

Mechanisation

It is for this same reason that Gandhi is opposed to large scale mechanisation. If mechanisation also ensures for all economic independence and freedom from greed (which is not likely), he would have no objection to it. But historically, British textile industry broke India's economic and consequently political and spiritual independence Hence all large scale industry has become for Gandhi the convergent symbol of exploitation.

Asked once whether he was against all machinery, Gandhi replied, "My answer is emphatically "No". But I am against its indiscriminate multiplication. I refuse to be dazzled by the seeming triumph of machinery. I am uncompromisingly against all destructive machinery. But simple tools and instruments and such machinery as "save" individual labour and lighten the burden of the millions of cottages I would welcome [5]. Again, "What I object to is the craze for machinery, not machinery as such. The craze is for what they call labour-saving machinery. Men go on 'saving labour' till thousands are without work and thrown on open streets to die of starvation. I want to save time and labour, not for a fraction of mankind, but for all; I want the concentration of wealth not in the hands of few, but in the hands of all. Today machinery merely helps a few to ride on the backs of millions. The impetus behind it all is not philanthropy to save labour, but greed. It is against this constitution of things that I am fighting with all my might [6].

As large-scale machinery or mechanised industry is the symbol of exploitation and enslavement, the human hand or manual labour is the Gandhian symbol of freedom and spiritual joy. Labour has a premium over capital or material resources, because labour is the prime factor in the creation of economic value. To contribute to the creation of this value therefore and in order not to be dependent nor greedy of exploitation, everyone must work manually. And capital, whether made with labour of one's own hands or inherited from the labour of others, must be held in trusteeship to the community which has helped to create it. That is why in the Gandhian economy there is strictly speaking no private property. This Gandhian economy marks a great step forward from capitalism [7].

Conclusion

The non-violent non-cooperative approach to conflicts and agitations differentiates the Gandhian economy from the Communist and other violence-borne approaches. To sum up, it may be said that due regard being had for equality and fraternity, and for the last and the least in the economic community, each would contribute according to his ability and

receive according to his need. This in brief is the Gandhian answer to our socio-economic problem.

Gandhian economics can be traced to a double tradition: the written tradition of the ideas of Bondueref and Tolstoy of Russia and of Ruskin of England and the Isopanishad of India on the one hand, and the unwritten but lived tradition of his own ashrams in South Africa and India on the other. Though not enunciated as a systematized body of thought, but rather spoken and written about at different times, Gandhian economics does still have the unity and consistency of a good life that has been well thought out. Its beauty does not minimize the difficulty of implementing the Gandhian economies. It would seem to be designed for saints like him- self. In breaking every idol of conventional economics and placing man, the universal man, at the centre of every economic decision, Gandhi has really proved to be a revolutionary prophet.

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Impact of Indian Knowledge System on the Holistic Development of Students in Higher Education Institutions

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ABSTRACT

The Indian Knowledge System (IKS), rooted in ancient cultural and educational practices, provides a holistic approach to student development, encompassing intellectual, emotional, ethical, and social dimensions. This paper explores the impact of IKS on holistic student development through its emphasis on interdisciplinary learning, ethical values, mindfulness practices, environmental responsibility, and traditional arts. By integrating IKS into modern educational frameworks, students gain a well-rounded education that fosters critical thinking, emotional resilience, and a deep respect for nature and society. This research presents IKS as a viable and valuable component in cultivating holistic student development within contemporary education.

Keywords: *Indian Knowledge System, holistic development, interdisciplinary learning, environmental responsibility, traditional knowledge.*

Introduction

Holistic education has gained increasing significance in today's rapidly evolving educational landscape, which requires students to possess more than just technical skills. The Indian Knowledge System (IKS) offers a rich and interdisciplinary approach to learning that emphasizes intellectual, emotional, and ethical development. Rooted in ancient Indian texts, philosophies, and practices, IKS promotes values like respect for nature, community engagement, ethical conduct, and lifelong learning. This paper examines how the integration of IKS within educational frameworks can foster holistic growth among students and contribute to the cultivation of balanced, socially responsible, and innovative individuals.

Objectives

- To explore the components of the Indian Knowledge System that contributes to holistic student development.
- To examine the potential impacts of IKS on various dimensions of student growth: intellectual, emotional, social, ethical, and creative.

- To assess the relevance and adaptability of IKS in modern education for developing well-rounded individuals.

Literature Review

Scholars such as Bhattacharya & Bhatia (2019) [2] and Agrawal (2020) [1] describe IKS's holistic approach to education, integrating disciplines like philosophy, science, mathematics, and ethics. However, beyond Sanskrit and Vedic texts, Tamil classical literature such as Thirukkural (Thiruvalluvar) and Naladiyar offer profound insights into ethical living, governance, and moral wisdom. These texts emphasize values that align with IKS, promoting social responsibility and personal integrity [5].

Additionally, works such as Panchatantra and Hitopadesha highlight moral storytelling as an effective pedagogical tool, reinforcing ethical decision-making skills among students (Iyengar, 2020) [3]. The philosophical teachings of Bhagavad Gita further strengthen the discourse on duty, self-discipline, and righteousness, which are core aspects of holistic education [4].

Methodology

This paper highlights the enduring relevance of IKS for fostering balanced, culturally rooted, and ethically aware students in modern educational systems.

The Indian Knowledge System (IKS) has a profound impact on the holistic development of students, enriching them intellectually, emotionally, and ethically. Rooted in ancient traditions, IKS emphasizes interconnected learning, encompassing fields like philosophy, mathematics, medicine (Ayurveda), linguistics, arts, and environmental sciences. Here's how it contributes to students' holistic development:

1. Intellectual Growth through Multidisciplinary Learning

- IKS promotes interdisciplinary learning, where subjects like mathematics, astronomy, and philosophy are interconnected. This multidisciplinary approach encourages students to think critically and connect ideas across fields, fostering intellectual flexibility [2].
- For example, ancient Indian mathematics (like the concept of zero and geometry from Vedic texts) not only sharpens analytical skills but also connects students to the historical and cultural roots of science.

2. Ethical and Moral Development

- Texts like the Vedas, Upanishads and teachings of leaders like Mahatma Gandhi introduce students to principles of ethics, self-discipline, compassion, and respect for all beings [1]. This moral grounding nurtures responsible citizens and compassionate individuals.

- The philosophy of non-violence (Ahimsa) and the concept of “Vasudhaiva Kutumbakam” (the world as one family) instils in students respect for diversity and peace [4].

3. Emotional Well-being through Mindfulness and Yoga

- Indian Knowledge Systems emphasize mental well-being through practices like meditation, mindfulness and yoga. These practices help students manage stress, increase focus, and foster emotional resilience [2].
- Studies have shown that incorporating yoga and mindfulness into school curricula can enhance concentration, reduce anxiety, and boost emotional health.

4. Connection to Nature and Environmental Responsibility

- The Indian Knowledge System teaches the interconnectedness of life, emphasizing sustainability and respect for the environment [5]. Concepts like “Prakriti” (nature) and “Pancha Mahabhutas” (the five elements) inspire students to understand their role in ecological balance.
- Such knowledge fosters environmental awareness and responsibility, crucial for building a generation that values and protects nature.

5. Encouraging Creativity and Artistic Expression

- Traditional Indian arts, such as music, dance and fine arts, allow students to explore creativity while understanding cultural heritage [3]. For instance, learning Indian classical music, with its intricate rhythms and improvisation, promotes creative thinking.
- Engaging in such creative practices contributes to a balanced personality, combining intellectual rigor with artistic sensibility.

6. Social Skills and Community Engagement

- Through its communal approach to education and the emphasis on “Gurukul” (teacher-student community learning), IKS nurtures social skills. Students learn the importance of community, shared learning, and respect for elders and teachers.
- Group discussions, community service, and cooperative activities within this framework build teamwork and empathy, helping students become active, socially responsible individuals.

7. Holistic Health and Wellness through Ayurveda

- IKS incorporates Ayurveda, an ancient Indian system of health and wellness, promoting a balanced lifestyle that includes proper nutrition, exercise, and a positive mental outlook [1].
- By learning about Ayurveda, students develop a sense of physical self-care and holistic health awareness, which contributes to overall well-being.

Findings

The study finds that IKS substantially impacts holistic student development by encouraging:

Intellectual Development: Multidisciplinary integration linking mathematics, philosophy, and ethics [2]. The study identifies the influence of IKS-based learning models in enhancing problem-solving and analytical thinking.

Ethical Development: Moral teachings from texts like the Upanishads, Thirukkural and Naladiyar instil compassion and ethical responsibility [5]. Ethical dilemmas and decision-making models inspired by these texts improve student judgment skills.

Emotional Wellness: Yoga and mindfulness practices enhance emotional resilience [4]. Institutions implementing structured meditation programs report higher levels of student focus and lower anxiety levels.

Environmental Responsibility: IKS principles emphasize sustainable living and respect for nature [1]. Concepts such as Ahimsa (non-violence) and Dharma (righteous duty) reinforce the ecological consciousness of students.

Creativity and Arts: Traditional arts encourage creative expression and cultural appreciation [3]. The practice of Indian classical dance and music enhances cognitive flexibility and artistic innovation.

Social Skills: The communal Gurukul system fosters teamwork and community engagement. Group learning methodologies embedded in IKS strengthen collaboration and social empathy.

Conclusion

In conclusion, integrating the Indian Knowledge System (IKS) into modern higher education offers a transformative approach to cultivating well-rounded, responsible, and resilient individuals. By emphasizing interdisciplinary learning, ethical values, mindfulness practices, environmental awareness, and creative expression, IKS contributes to the holistic development of students, extending beyond technical or academic skills. This study underscores how IKS can foster intellectual rigor, emotional balance, and social responsibility, equipping students to navigate contemporary challenges with a strong sense of cultural identity and ethical grounding. As educational institutions strive to create more holistic learning environments, incorporating IKS into curricula holds significant promise for developing students who are not only knowledgeable but also compassionate, culturally rooted, and conscious of their roles in a diverse and interconnected world. These insights call on policymakers and educators to explore the potential of IKS to enrich modern education, thereby nurturing a generation of thoughtful, empathetic, and innovative leaders.

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Problems Faced by Women in Rural Areas

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ABSTRACT

The role of women folk in economic development is unavoidable and unforgettable. Each and every one of the work done by the women folk in various sectors made a tremendous changes in the India economy. Though women are in the high position they are not in a good situation and also struggle a lot both socially and economically in the rural areas. Women in the remote areas face challenges that impede their personal development and hinder community progress. This paper explores the multifaceted issues of limited access to education, economic disparities, inadequate healthcare, gender-based violence, limited political participation, and cultural barriers, environmental challenges, technological exclusion, and inadequate infrastructure. As a developing economy we can develop targeted strategies to educate and improve their overall quality of life.

Keywords: *Sustainability, Communities, Development, Opportunities, Tradition*

1. Introduction

The role of women folk in economic development is unavoidable and unforgettable. They play an important role in boosting the economic development. Work done by the female folk in various sectors made tremendous changes in the India economy. Though women are in the high position they are not in a good situation and also struggle a lot both socially and economically especially in the rural areas. Women are critical to the development and sustainability of rural communities, yet they often encounter unique barriers which make them stay in the four walls of the house and which are deeply rooted in socio-economic, cultural, and geographic contexts. Addressing these issues shows a path to the empowerment of women and also for the overall progress of rural societies.

Objectives

- To identify the challenges of the women in rural areas
- To suggest solutions to overcome the barriers

2. Challenges of Rural Women

i) Limited Access to Education

Education is a fundamental right and a key driver of development in every one's life. However, in rural areas girls are systematically affected in educational opportunities. Families often prioritize boys' education due to traditional beliefs and economic considerations, viewing sons as future breadwinners. Girls may be withdrawn from school early to assist in the household responsibilities or to marry young. This educational inequity perpetuates poverty and limits women's opportunities for economic independence.

ii) Economic Disparities

Economic chances for women in the village are often restricted. Many women rely on subsistence agriculture or informal employment, which tends to be less stable and lower-paying than formal jobs. Gender wage gaps are pronounced, with women frequently earning less than their male counterparts for similar work. Furthermore, women miss the access to financial resources, such as credit or land ownership and contract their ability to start small scale industries for their futures.

iii) Healthcare Access

Healthcare is a significant concern for rural women. Rural areas are underserved by healthcare facilities and practitioners, making it difficult for women to receive necessary medical care. This is particularly concerning for maternal health; complications during childbirth can have severe consequences. Cultural stigmas surrounding reproductive health can also seek medical assistance, leading to preventable health issues. Without adequate healthcare access, women's physical and mental well-being suffers, further entrenching their vulnerabilities.

iv) Gender-Based Violence

Gender-based violence (GBV) is an issue which spreads throughout the rural areas. Women often face domestic violence, sexual harassment, compounded by social separation and a lack of protections. Cultural norms may discourage women from reporting violence, and local law enforcement may be unsympathetic or ineffective in addressing their claims. This perpetuates a culture of silence around GBV, exacerbating its impact on women's lives and hindering their ability to participate fully in society.

v) Cultural Barriers

Cultural beliefs and practices significantly shape the experiences of women folk. The cultural barriers can affect all aspects of life, from education and healthcare to economic

participation and political involvement. Challenging these entrenched norms is crucial for contributing to their communities.

vi) Lack of Vocational Training

Moreover, women often miss out on vocational training which can enhance their employability. This lack of vocational training leaves women underprepared for more skilled jobs, perpetuating their economic marginalization

vii) Barriers to Leadership

Barriers to leadership roles also exist, as women may be perceived as less capable or credible leaders compared to men. This perception can prevent women from gaining positions of influence in their communities, further marginalizing their perspectives.

viii) Stigmatization of Women's Rights Activism

Efforts to promote women's rights can also face stigmatization. Women who advocate for gender equality may be seen as challenging traditional values, leading to backlash or ostracization from their communities.

ix) Environmental Challenges

Women in rural areas often bear the brunt of environmental issues and natural disasters. As primary caregivers and gatherers of resources like water and firewood, they are forced to play the role of environmental degradation.

x) Impact on Livelihoods

Changes in climate can disrupt agriculture, which are essential for women's livelihood which leads to food insecurity, increased workloads, and economic instability, further compounding existing challenges.

xi) Technological Exclusion

In the digital world, access to technology is needed for economic and social advancement. However, uneducated women are facing barriers to accessing technology and the internet, lack of updating, market products, or connection with broader networks.

xii) Lack of Training in Technology

Though technologically advanced nations, lack training the women folk are not able to give their hundred percent results in the digital nation. This exclusion from the digital economy further exacerbates gender disparities in rural areas.

xiii) Inadequate Infrastructure

In many rural areas, inadequate infrastructure such as poor transportation, unreliable electricity, and lack of clean water poses significant challenges for women. These

deficiencies can affect their livelihood, healthcare, and employment opportunities, further entrenching their marginalization.

3. Remedial Measures

Rural women are facing numerous challenges which stop their personal growth as well as the progress of their communities. The challenges require comprehensive and multifaceted strategies. The remedial measures that can be implemented to empower women and improve their overall quality of life in rural areas.

i. Enhancing Access to Education

Investing in schools, colleges and vocational training centers in rural areas can increase access for girls. Community awareness programs can help change attitudes toward girls'. Implementing scholarship programs for girls can alleviate the financial burden on families and societies. Incentives like stipends for school attendance can encourage families to give education.

ii. Economic Empowerment

Establishing microfinance institutions tailored to women can provide necessary capital to start business. Economic empowerment helps women to manage their finances effectively. Collaborations with NGOs and local businesses help to know the market conditions. Mentorship and networking opportunities can foster collaboration and knowledge sharing, helping women navigate business challenges.

iii. Improving Healthcare Access

Building more healthcare facilities in rural areas, staffed with trained professionals, can improve access to essential services, particularly maternal and reproductive health care. Implementing mobile health clinics can reach remote communities, provide preventive care and health education, and directly focus on women's health issues which empower women's health and well-being.

iv. Combating Gender-Based Violence

Strengthening legal protections against gender-based violence is essential. This includes enforcing laws, providing legal aid, and establishing shelters for victims. Raising awareness about GBV through community programs can help change societal attitudes, encouraging victims to speak out and seek help. Training law enforcement officials to handle cases of GBV sensitively and effectively can improve reporting and support for victims.

v. Increasing Political Participation

Training programs like leadership skills, advocacy, and managerial skill generate women leaders to participate in political processes and decision-making. Implementing

policies that require a certain percentage in local governance, women's voices are represented in decision-making.

vi. **Challenging Cultural Barriers**

Facilitating open discussions within communities about gender roles and women's rights can help challenge traditional norms and promote gender equality. Involving men and boys in gender equality initiatives can help change attitudes and behaviors of women.

vii. **Addressing Environmental Challenges**

Training women in agricultural practices can enhance food security and economic stability, making them more resilient to environmental changes. Resources like water and energy can reduce their workload and improve their quality of life, allowing them to focus on education and economic opportunities.

viii. **Bridging the Digital Divide**

Investing in infrastructure to provide reliable internet access in rural areas can open up opportunities for education, entrepreneurship, and information sharing. Offering digital literacy improve the knowledge and skills needed to utilize technology effectively, enhancing their participation in the digital economy.

ix. **Improving Infrastructure**

Investing in transportation infrastructure can facilitate a way to education, healthcare, and employment opportunities for women, reducing isolation. Improving access to clean water and sanitation facilities improve the well being for women and reduce the time spent on domestic chores.

4. Conclusion

Women folk in the rural areas are facing so many problems. The challenges are complex and interrelated, requiring a multifaceted approach to address them effectively. Initiatives that promote education, provide economic opportunities, improve healthcare access, and foster participation in all activities are essential for empowering rural women. Additionally, efforts to change the attitude towards gender can create a better environment. By addressing these issues holistically by implementing these remedial measures, we can create gender equality. Empowering women in the rural areas not only enhances their lives alone but also strengthens the social and economic fabric of the society as a whole.

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A Comparative Study on Online and Offline Shopping in Madurai

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ABSTRACT

In today's competitive market, consumer preferences are shaping the strategies of sellers more than ever. Meeting these evolving demands requires businesses to adopt innovative models that blend the digital and physical shopping experiences. Hybrid solutions are emerging, such as online payment with offline store pick-up, online marketing combined with in-store ordering, and fully integrated online-to-offline (O2O) services. The O2O model stands out by building a seamless bridge between physical stores and online platforms. It empowers consumers to experience products firsthand in brick-and-mortar stores while completing the purchase and payment process online. Compared to traditional B2C models, O2O offers a dynamic approach those appeals to potential buyers seeking flexibility and convenience. This paper explores the decision-making process behind consumer choices when navigating between online and offline shopping channels. We aim to understand how individuals evaluate the factors influencing their purchasing behaviour and how businesses can align their online platforms with physical stores to create cohesive customer journeys. Several factors influence demand for products, from convenience and price sensitivity to the tactile experience of physical shopping. Interestingly, consumer behaviour can shift rapidly based on these variables. For instance, a sudden desire for same-day gratification may pull shoppers toward a nearby store, while competitive pricing or exclusive online deals might push them toward e-commerce. Despite the undeniable rise of online shopping, traditional stores continue to maintain their relevance by offering experiences that digital platforms cannot replicate. In this paper, we'll explore the pros and cons of both shopping systems to help consumers make informed decisions and to guide businesses in designing better retail experiences. By delving into literature and analysing consumer behaviour patterns, this research proposes a practical framework for understanding the working mechanisms of O2O models and how they influence consumer evaluations. As the retail landscape continues to evolve, businesses must adapt by recognizing and responding to these shifting preferences, thereby bridging the gap between clicks and bricks for a truly omnichannel experience.

Keywords: Online-to-Offline (O2O) Model, Consumer Behaviour, Omnichannel Retailing

Introduction

As technology advances rapidly, the way businesses connect with consumers continues to evolve, offering faster and more innovative service models. One such approach is the O2O (Online to Offline) model, which seamlessly blends the virtual marketplace with

traditional store experiences. This hybrid strategy introduces diverse transactional methods, such as online payments with in-store pickup, online marketing with physical store orders, and offline experiences combined with digital payments.

Unlike conventional B2C models, O2O builds a vital bridge between brick-and-mortar stores and online platforms, allowing customers to physically experience products before making online purchases. This synergy reshapes consumer behaviour, offering flexibility and convenience.

Despite the meteoric rise of e-commerce, physical stores continue to hold their ground by delivering an unmatched tactile experience. Traditional shopping allows customers to see, touch, and try products while interacting with knowledgeable staff who provide personalized guidance. On the other hand, online shopping offers the convenience of browsing and purchasing products anytime, anywhere, without the constraints of physical travel or store hours.

Both channels offer unique advantages — online stores provide extensive product selections and global accessibility, while in-person shopping supports local businesses and offers immediate product gratification. In this analysis, we dive deep into the relative benefits and challenges of both systems, helping you make informed choices in your shopping journey.

Factors Affecting Online Shopping

Online shopping has become a transformative trend in consumer behaviour, offering distinct advantages over traditional methods. Its rising popularity proves that it provides benefits not available in offline shopping. Let's explore the factors influencing this shift:

1. Risk Factor

One of the primary reasons older generations hesitate to shop online is the perceived risk. Customers often find it challenging to gauge how products seen on a screen will perform in real life. Issues such as:

- fitting clothes
- Faulty appliances
- Leaky containers

Difficult return processes create skepticism. Trust is built when websites offer clear quality guarantees and efficient return policies.

2. Design and User Experience: The design and usability of a website significantly impact online shopping behaviour. Factors such as:

- Easy navigation
- Responsive interfaces

- Personalization options

influence consumer satisfaction. Research by Masínová and Svandová (2014) demonstrated that a well-designed website plays a critical role in customer engagement.

3. Pricing and Discounts

Pricing is a crucial determinant of online shopping decisions. Customers are drawn to platforms that offer:

- Attractive sales
- Free delivery options
- Discounts on products

Shoppers are more likely to choose online stores when they find sports accessories or other items at a 30% discount rather than at full price.

4. Psychological Factors

Emotional and psychological elements subtly influence consumer behaviour. Elements such as:

- Aesthetic design
- Website response speed
- Colour schemes

can either encourage or deter future interactions. Positive online experiences are often associated with pleasure, goal achievement, and user engagement.

5. Other Influencing Factors

- Age group preferences
- Spam or virus risks
- Annoying emails
- Nature of products being sold
- Previous shopping experiences

These factors collectively determine the long-term success of an e-commerce site.

Key Factors Impacting Offline Shopping:

Shopping has been an integral part of human life for centuries, and despite the growing dominance of online shopping, offline shopping continues to offer a range of distinct advantages. Here are some key factors influencing customers' preferences for traditional shopping:

1. Limited Selection of Products

Offline shopping tends to offer a more restricted range of choices compared to online shopping. The variety available is confined by store space, inventory, and local demand.

Products on display may also be older stock, discounted or clearance items, which can limit the options available to customers. The number of choices is typically smaller due to the reliance on physical stock management and manual processes.

2. Time-Consuming Experience

Offline shopping can be a more time-intensive experience. Shoppers often need to travel from one store to another, searching for specific products. The process of trying on clothes, examining products, and navigating crowded stores can take up significant time, making it less efficient than the online shopping experience, where items are just a click away.

3. Authenticity of Products

One of the strongest reasons for offline shopping's appeal is the authenticity it offers. Shoppers can physically examine products, feel their texture, and assess their quality before making a purchase. This direct interaction helps ensure they are getting exactly what they expect. In contrast, online shopping often involves uncertainty, as the product in the pictures may look different upon arrival due to lighting, camera angles, or even inaccurate descriptions.

4. Bargaining Power

A unique benefit of offline shopping is the ability to negotiate prices directly with the seller. Shoppers can haggle for discounts, especially in markets or smaller stores, creating a more personalized and flexible shopping experience. Online prices are fixed, leaving little room for negotiation, which can deter shoppers who enjoy the bargaining process and feel it provides them with a better deal.

5. Tactile Experience – Feel and Touch

Offline shopping allows customers to physically interact with products, offering the chance to feel their material, check their weight, and evaluate their overall quality. This tactile experience helps buyers make more confident decisions. In contrast, online shopping relies heavily on visuals and descriptions, which can sometimes fall short in conveying the true quality of the product.

Objectives

- To compare consumer behaviour across different districts.
- To identify the benefits and drawbacks of offline shopping in Madurai.
- To understand consumer preferences and patterns in shopping.

Analysis of Data

i) Problems Faced by Consumers in Online Shopping

Results of Garrett Ranking Technique

Factor	Total Score	Average Score	Rank
Lack of Security	60	46.4	V
Poor Quality	15	56.6	I
Delay in Delivery	55	50.2	II
Out of Stock	40	49.6	III
Payment Process	90	47.6	IV

Source: Computed Data

Based on the computed data, the table reveals that the most significant issue faced by respondents was poor product quality, which ranked first with an average score of 56.5. Following this, delays in delivery were the second most common problem, with an average score of 50.2. Out-of-stock items ranked third, with a score of 49.6, while payment processing issues were ranked fourth at 47.6. Lastly, concerns over a lack of security were ranked fifth, with an average score of 46.4 in the study area.

ii) Problems Faced by Consumers in Offline Shopping

Results of Garrett Ranking Technique

Rank	Problem	Average Score
1	Non-availability of Desired Product	74
2	Damaged Products	55.8
3	Poor Replacement of Products	46
4	Unavailability of Discounts/Offers	38.6
5	Poor Packaging	35.2

Source: Computed Data

As per the table, non-availability of the desired product emerged as the most significant issue, scoring the highest at 74. The damaged products problem ranked second with a score of 55.8. Other issues such as poor replacement of products, lack of discounts or offers, and poor packaging followed in severity, with scores of 46, 38.6, and 35.2, respectively.

Findings

- **Age Demographics:** 60% of the respondents fall in the 15 to 25 age group.
- **Income Levels:** 52% of respondents earn between ₹35,000 and ₹50,000 per month.
- **Shopping Preferences:** 48% of respondents prefer offline shopping, while 56% shop online to take advantage of discounts.
- **Spending Patterns:** 56% of respondents typically spend ₹200 to ₹500 per shopping trip.

Reasons for Shopping Preferences

- **Offline:** 48% choose offline shopping to avoid delivery charges.
- **Online:** 52% prefer online shopping for purchasing furniture.
- **Purchase Categories:** 44% prefer customized products through offline channels, while 44% follow a hybrid approach of online-to-offline shopping.

Challenges Faced

- Top Issues in Online Shopping:
- Non-availability of desired products (74 average score)
- Damaged products (55.8)
- Poor product replacement (46)
- Limited discounts or offers (38.6)
- Poor packaging (35.2)

Top Issues in Offline Shopping

- Poor product quality (49.6)
- Complex payment processes (47.6)
- Security concerns (46.4)

Suggestions

Improving Traditional Shopping

- Stores should enhance customer convenience by clearly displaying product availability and prices through their websites or other channels.
- Providing a price comparison feature across different shops could be beneficial.

Enhancing Online Shopping

- Strengthen return policies and offer payment-on-delivery options to boost consumer confidence.
- Improve customer data protection and payment security measures to create a safe shopping environment.

Quality Assurance

- Both traditional and online sellers should prioritize product quality and ensure proper packaging to meet customer expectations.

Security Improvements

- Guarantee secure payment options and safeguard customer information to build trust in online transactions.

Conclusion

The study highlights key differences between traditional and online shopping experiences. While traditional shopping is perceived as safer with no risk of online fraud, it lacks the flexibility and product variety that online shopping offers. Conversely, online shopping appeals to consumers with the convenience of home delivery and attractive discounts but faces challenges related to product quality, replacements, and security concerns. To bridge these gaps, both shopping models need continuous improvement to meet evolving consumer expectations and foster a seamless shopping experience.

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Socio-Economic Conditions of Handloom Weavers: A Case Study of Balaramapuram Area

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ABSTRACT

In recent days, the sector is seen losing its relevance in the Industrial scenario of the state due to several reasons. This Industry is facing a severe crisis due to increased cost of production, marketing difficulties and encroachment of power looms and lack of human resources. Despite all the rejuvenating measurements from the state government, the handloom sector is still failing in its own ways. This study examines the social and economic conditions of handloom weavers in Balaramapuram, Kerala state. This study analyse about problems of the handloom industry in Kerala such as lack of adequate working capital.

Keywords: Market demand, Skill development, working conditions, Cultural heritage

Introduction

The handloom sector of Kerala is very relevant in the state with the most sought of clothes. In case of employment, handloom is the second largest sector next to agriculture in India. India has a long tradition in weaving, especially in hand weaving. According to the census in 2011, it is estimated 833 million people are currently living in India. In which more than 35 million weavers and 15000 weaver's co-operative societies are built up on their dream with the support of the handloom industry. The handloom industry is expanding not only nationally but also internationally because of the demand for handcraft artifacts and unique traditional design.

Significance of the Study

- Handloom sector played a pivotal role in the country's economy.
- It is one of the largest economic activities providing direct employment to over 65 lakh persons engaged in weaving and allied activities.
- Handloom sector contributes nearly 19% of total cloth production in India during 2019-2020.

- However, the Handloom industry in Kerala faces all problems and challenges due to increased cost of production, marketing difficulties, encroachment of power looms and Lack of human resources.
- This research aims to study the problems and prospects of traditional weavers in modernized world and thus significant

Objectives

- To know the working status of the sample respondents.
- To know the income level of the sample respondents.
- To study the major problems faced by the weavers.

Methodology

This study is undertaken based on households in Balaramapuram area. Sample sizes are restricted to 50 households. Primary data are collected with the help of structured questionnaires. Secondary data sources are publications of state government, books, magazines, newspapers and government sites. Convenient Random Sampling Method used.

Data Analysis

1. Age of Weaver

Sl. No	Age Group	No. of Respondents	Percentage
1	Less than 40 years	6	12
2	41-50	8	16
3	51-60	24	48
4	Above 61	12	24
TOTAL		50	100

Source: Primary Data

The table 1 shows that 12 percentage of the sample respondents are less than 40 years of age and 48 percentage of the sample respondents are above 61 years are also engaged in the weaving

Education of the Weaver

Sl. No	Education of Weaver	No. of Respondents	Percentage
1	Illiterate	13	26
2	Primary level	18	36
3	High School level	13	26
4	Higher Secondary level	3	6
5	Graduated	3	6
TOTAL		50	100

Source: Primary Data

The above table 2 shows that 36 percent of weavers have Primary school education and 6 percent of the sample respondents are graduates. Less government intervention to enhance the weaver's education is the reason for the low level of education of the weaver.

3. Reasons for Entering in to Weaving Profession

Sl. No	Reasons	No. of Respondents	Percentage
1	Hereditary	35	70
2	Only work known	15	30
TOTAL		50	100

Source: Primary Data

Table 3 shows that 70 percent of the weavers chose this profession as weaving is their hereditary job and 30 percent of the sample respondents entered into the profession due to only the work known.

4. Working Status of Weaver

Sl. No	Working Status	No. of Respondents	Percentage
1	Independent weaver	37	74
2	Under master weaver	13	26
TOTAL		50	100

Source: Primary Data

Table 4 shows that 74 percent of the sample respondents are independent weavers who have their own looms and do the weaving in their own house. Whereas 26 percent of the sample respondents are under master weavers and no one is Cooperative weaver.

5. Working Hours per Day

Sl. No	Working Hours	No. of Respondents	Percentage
1	Up to 6 hours	13	26
2	7-9 hours	11	22
3	10-12 hours	13	26
4	Above 13 hours	13	26
TOTAL		50	100

Source: Primary Data

Table 5 explains that 22 percent of the sample respondents' works for 7-9 hours per day, 26 percent of the sample respondents work for up to 6 hours a day, 10-12 hours a day and more than 13 hours.

6. Experience in Hand Loom Weaving

Sl. No	Years of Experience	No. of Respondents	Percentage
1	Below 5 years	1	2
2	6-10 years	2	4
3	11-15 years	2	4
4	16-20 years	15	30
5	Above 21 years	30	60
TOTAL		50	100

Source: Primary Data

Table 6 shows that 60 percent of the sample respondents have an experience of weaving above 21 years.4 percent of the sample respondent have an Experience of 11-15 years and 6-10 years.

7. Monthly Income

SL.NO	Monthly income	No. of Respondents	Percentage
1	Below 5000	18	36
2	5000-9000	29	58
3	Above 10000	3	6
TOTAL		50	100

Source: Primary Data

Table 7 shows that 36 percent of the sample respondents earn a monthly income below 5000 and 6 percent of weavers are getting above 10000 as monthly income.

8. Health Problems

Sl. No	Health Problems	No. of Respondents	Percentage
1	Eyesight	9	18
2	Back Pain	9	18
3	Joint Pain	13	26
4	Other	8	16
5	Nil	11	22
TOTAL		50	100

Source: Primary Data

Table 8 shows that the most common health problem is joint pain which is 26% of the weavers and 18% weavers having back pain. 18% of weavers have eyesight and 16% complain about other illnesses like too much pain, headache etc. and increasingly about 22% have no complaint about their health.

Findings

- Majority of the weavers belong to the female category with the proportion of 90 Percentage and 10 Percentage of the people were male. There are no transgender employees working in the handloom industry where the research is carried out.
- 12 Percentage with the proportion of 48 Percentage and people above 61 years are also engaged in weaving with the proportion of 24 Percentage. The people between 41 to 50 years are engaged in the weaving process with 16 Percentage.
- 26 Percentage of weavers have High school education and 36 Percentage of weavers are having primary education. 26 Percentage people are illiterate and only 6 Percentage people have graduated. Less government intervention to enhance the weaver's education is the reason for the low level of education of the weaver.
- 38 weavers have their own house that covers 76 Percentage of the total sample collected for the study. Only 24 Percentage of weavers are leading their life in rented houses.
- 22 Percentage of the respondents work for 7-9 hours per day, 26 Percentage work for up to 6 hours a day, 26 Percentage work for 10-12 hours a day and 26 Percentage of people work for more than 13 hours.
- 60 Percentage of weavers have an experience of weaving above 21 years. 30 Percentage

have an experience of 16-20 years. 4 Percentage of having an Experience of 11 - 15 years. 4 Percentage of them having the experience of 6 – 10 years.

- 36 Percentage earn a monthly income below 5000 only and 58 Percentage earn between 5000 - 9000 and 6 Percentage of weavers are getting above 10000 as monthly income.

Suggestions

- Salary of weavers should be increased to retain the sector.
- Steps should be taken by the government to increase handloom melas and exhibitions.
- Government must ensure to see all the Schemes inefficiently.
- Most of the Schemes are benefited by master weavers and co-operative society weavers. It needs to be to the benefits of independent weaver, labour weaver and under with Middle man.
- Take necessary steps to control the trade of fake products in the name of Balaramapuram Kaithari.

Conclusion

This study has examined the Socio-Economic Conditions of Handloom Weavers in Balaramapuram Thiruvananthapuram District. Handloom sector is a major traditional industry. But now it is in the edge of its extinction mainly due to the invasions of power loom. The problem faced by the handloom industry affect the life of weavers. As a part of it, the traditional weavers also face problems and challenges. They faced various socio-economic and physical problems and challenges. The weavers get wages and on time, but it is not sufficient to maintain the economic balance. So, they seek other job parallel to it. Major it you weavers are women and the male members in the family not only involve in weaving they also goes to other job parallel to weaving which have more income. So, this study reveals the majority of the family is not only depending on the handloom. But a small portion of people still completely depending on handloom

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Work-Life Balance and Mental Health Challenges among Women Professors: An Empirical Investigation

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ABSTRACT

Maintaining a healthy work life balance is crucial for the overall well-being and success of working women. A successful existence also depends on having good mental health. This study investigates the relationship between work life balance and mental health among the women professors. The primary objective of this study is to identify the factors affecting the work and life and mental health of women faculty members. This study underscores the significance of work life balance in working women's lives, highlighting the challenges of balancing career and personal commitments. Despite these challenges, a significant proportion of respondents successfully manage both commitments, employing various strategies to maintain equilibrium.

Keywords: *Work life balance, Mental Health, Sustainable lifestyle, Personal fulfilment, Social well-being, Personal and professional achievement.*

Introduction

Work-life balance is a condition of equilibrium that individuals strive to attain, where they successfully integrate their professional responsibilities with their personal life. Achieving this delicate balance enables individuals to merge their career aspirations with personal fulfillment, ultimately leading to a healthy and sustainable lifestyle.

Mental health is a multifaceted concept that encompasses emotional, psychological, and social well-being, exerting a profound influence on an individual's thoughts, feelings, and behaviors in their daily lives. Maintaining good mental health necessitates effective stress management, coping with the demands of work, and ensuring that personal well-being is not compromised in the pursuit of professional achievements.

Statement of the Problem

The work-life balance of women professors is a state of equilibrium that they strive to attain, where they efficiently prioritise, allocate, and manage their time to reconcile their work obligations with their personal life. This equilibrium ensures that their work commitments do not overshadow their personal pursuits and overall well-being. Maintaining

a healthy work-life balance is necessary for everyone, regardless of their profession or position. However, achieving and maintaining this balance can be a challenging task. Women faculty members' mental health is positively impacted by maintaining a healthy work-life balance, whereas a poor balance can have negative consequences. Conversely, instability in mental health can compromise work-life balance and job satisfaction, ultimately affecting efficiency and effectiveness within academic settings. Therefore, this research attempts to investigate the tactics employed by women professors to manage their work commitments and family responsibilities, and to investigate the effects of achieving a balance on their mental health.

Significance of the Study

This study undertakes an in-depth examination of the work-life balance of women faculty members, with a specific focus on its influence on their psychological well-being. The study offers a thorough and detailed account of the challenges that women faculty members encounter in managing their dual responsibilities of work and personal life. Additionally, this research endeavour investigates the various elements that affect women faculty members' work-life balance, and examines the strategies and techniques that they employ to effectively manage their personal and professional obligation. The study also examines the degree of life and work satisfaction among female faculty members and offers suggestions for how they might manage their many obligations without sacrificing their health.

Scope of the Study

The purpose of this study is to especially look into the mental health and work-life balance of female academics who work at the Arts and Science College in Nagercoil. This study's main goal is to determine and investigate the variables that affect women academics' work-life balance. Historically, women have faced numerous barriers to education, including being denied access to educational institutions due to widespread illiteracy and restrictive social norms. Women have, however, made great progress in the field of education in recent years, and they now hold a variety of roles in educational institutions, ranging from administration and management to teaching and research. These shifts have led to women taking on a variety of roles in society as well as in their homes. The imbalance between work and life seems to be most likely caused by conflicts between the demands of job and family requirements. The planned study will shed important light on the mental health and work-life balance of female professors and is socially relevant. Furthermore, the study's findings will contribute to improving the overall quality of life for working women.

Review of Literature

Eugene Elden Blalock (2024), conducted a study on “Teachers’ perception of how a 4-day school week impacts employee attendance, recruitment and retention, and wellness/work-life balance”. The purpose of this research-based report was to examine teachers’ perceptions of switching from a 5-day school week to a 4-day school week. This research showed that transitioning from a 5-day school week to a 4-day school week positively affected teachers’ perceptions. Overwhelmingly, teachers communicated how the 4DSW improved their wellness/work-life balance by allowing them to spend more time with their families and attend to their personal affairs.

Dr. Prasad Jeevan Pathak (2024), conducted a study on “Work-life balance – a key for job satisfaction and remedy to overcome job stress”. This study has gone further to determine and quote a few top factors that have an impact on the Job Satisfaction and Job Stress for the employees. This study concluded that there is an indirect relation between Job Satisfaction and Job Stress. More Job Satisfaction, less Job Stress. From the factors affecting the Job Stress and Job Satisfaction, Organisations should ensure to maintain Work-Life balance, Supportive work environment along with Employee Job Security. This will ensure low Job Stress and more Job Satisfaction among the employees. More the Job Satisfaction, the more the productivity of the employee.

Armaana Malhotra (2024), conducted a study on “Job Autonomy, Work life balance and Job Satisfaction among IT Professionals”. This study synthesizes research findings on work-life balance in the IT sector, examining various factors influencing employees' ability to manage work-related stressors and achieve satisfaction in both their professional and personal lives. It revealed a complex interplay of factors that influence employees' perceptions and well-being. Work-life balance significantly influences job satisfaction, with a strong positive correlation between WLB and JS. This study concluded that job autonomy, a key determinant of job satisfaction, may vary within the IT sector, with factors like task complexity, team dynamics, and organizational structure potentially impacting perceptions.

Dr. Anita Patel, Dr. Jacksan Judan Fernandes (2023), conducted a study on “The Essence of Work-Life Balance and Solutions”. The objective of this paper is to first comprehend the idea of work-life balance, its significance and problems in different professions, and then to determine how work-life balance impacts one's physical, economic, psychological, societal, spiritual, and environmental wellbeing of employees. It concluded that the Work-life balance rules are evident in most companies. Such solutions boost employee dedication, contentment, innovation, and problem-solving. However, work-life

balance is challenging to achieve due to the diversity of employee and company needs. Despite these challenges, it's evident that employees need an open, trusting, autonomous, and interactive workplace.

Objectives of the Study

- ❖ To examine and identify the various factors that affect the work-life balance and female faculty members' mental health.
- ❖ To investigate and explore the strategies and practices adopted by women faculty members to effectively balance their professional responsibilities and personal obligations.

Methodology

The researcher's goal in this study was to investigate the mental health and work-life balance of female academics. The data on women faculty members' work-life balance was gathered, examined, and tabulated.

Sampling Method

The study is descriptive and analytical. It is descriptive in the sense that it exists at present and it includes findings and facts. It is analytical in the sense that it involves analysis and interpretation of data. The required data relating to the research were obtained through a well-structured questionnaire. Simple random sampling, a non-probability sampling method, was employed for data collection.

Sample Size

Data was gathered from 115 respondents in the Nagercoil research region.

Sources for Collecting of Data

Data for this study was gathered from both primary and secondary sources.

Data Analysis Tools

The factors influencing work-life balance, the effect of mental health on job happiness, and the methods professors employ to manage their work-life obligations are all examined using statistical tools. Software called SPSS (Statistical Package for the Social Sciences) was used to analyse the data.

Data Analysis and Interpretation

Factors that impact mental health and work-life balance

Maintaining healthy professional-personal life equilibrium can be challenging due to competing demands and responsibilities that pull individuals in different directions.

Factors that impact mental health and work-life balance

Particulars	Mean score	Rank
Excess workload	8.52	I
Excess household work	7.55	III
Flexible work arrangements	6.58	VI
Family responsibilities	8.37	II
Equitable compensation for work performed	5.87	VII
Support from peers, family and management	6.83	V
Overtime working	7.43	IV
Administrative works	5.86	VIII
Colleagues' dismissive or cooperative attitude towards personal and family needs	3.50	IX
Family members' disapproval or lack of understanding regarding work demands	2.55	XI
Travelling far away from work place	2.94	X

Source: Primary Data

The above table reveals that excess workload ranks first with the mean score of 8.52 and family responsibilities ranks second with the mean score of 8.37 and excess household work ranks third with the mean score of 7.55 and family members disapproval ranks last with the mean score of 2.55. The majority of those surveyed believe that an excessive workload jeopardises their work-life balance.

Strategies to attain a balance between work and life

Effective management of work and life commitments requires intentional approaches and practices that promote balance and well-being.

Strategies to attain a balance between work and life

S. No.	Particulars	Mean score	Rank
1	Sharing family responsibilities with spouse/family members/Friends.	3.30	II
2	Completing lesson plans on schedule.	3.68	I
3	Completing all college related tasks on campus.	2.64	IV
4	Utilizing holidays to spend quality time with family.	2.33	V
5	Adapting and gaining new knowledge	3.05	III

Source: Primary Data

The above table reveals that the completion of portion on time ranks first with the mean score of 3.68 and sharing family responsibilities ranks second with the mean score of 3.30 and adapting new knowledge ranks third with the mean score of 3.05 as well as spending time with family ranks last with the mean score of 2.33. The significant proportion of the respondents should complete their teaching portions on time; this will help to manage the work and life commitments.

Findings

- ❖ Excess workload ranks first with the mean score of 8.52 and family responsibilities ranks second with the mean score of 8.37 and excess household work ranks third with the mean score of 7.55 and Family members disapproval ranks last with the mean score of 2.55.
- ❖ Completion of portion on time ranks first with the mean score of 3.68 and sharing family responsibilities ranks second with the mean score of 3.30 and adapting new knowledge ranks third with the mean score of 3.05 and utilizing holidays to spend quality time with family ranks last with the mean score of 2.33.

Suggestions

- ❖ Many respondents expressed challenges in prioritizing self-care and finding time for personal hobbies due to overwhelming academic demands. To mitigate this issue, professors can establish clear boundaries and realistic expectations for academic work, thereby preventing it from encroaching on their personal lives.
- ❖ Respondents cited numerous distractions during work hours, leading to overtime. To address this, professors can utilize time-blocking tools to schedule reminders and breaks, enhancing productivity and work life balance without compromising academic rigor.
- ❖ Most respondents reported that excessive workload negatively impacts their work life balance. To mitigate this, they propose delegating less urgent tasks, setting realistic Work Hour Limits and Prioritizing Manageable Tasks Based On Deadlines.

Conclusion

Work life balances are very crucial in every working woman's life and maintaining the optimal mental well-being is also essential to live their life peacefully. This study underscores the significant role of work life balance in working women's lives, highlighting the challenges of balancing career and personal commitments. Despite these challenges, the significant proportion of the respondents successfully manages both commitments, employing various strategies to maintain equilibrium. However, a notable exception

emerged, as some respondents sacrificed quality family time. However, the study found that the majority of participants were content with their present work-life balance.

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The Impact of Financial Management on Investment Strategies and Outcomes

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ABSTRACT

Financial management is the strategic organizing, directing, and controlling of financial activities within a company or individuals. Investments are defined as an asset or item acquired with the intention of generating revenue or recognition. In an economic outlook, an investment is the purchase of goods that will be utilized to generate value later on but are not used immediately. Financial management is essential in investments because it enables people and organisations to make well-informed decisions regarding the distribution of their financial resources to meet their investment goals. Individuals can create investment plans that fit their objectives and risk tolerance. In order to create a balanced investment portfolio, this may entail choosing suitable investment channels, such as stocks, bonds, mutual funds, or real estate, and figuring out the right asset allocation. This study aims to know about the financial management practices on investment performance.

Keywords: *Financial management, Investment, Investors, Decision making*

Introduction

An investment is a financial instrument designed to facilitate the accumulation of wealth over time and to secure future monetary demands. Investments may result revenue in two ways. 1) Making a purchase of a salable commodity that could generate a profit. 2) Investing in a plan that will provide returns and income through capital gains. Financial management involves planning, organizing, controlling, and monitoring an organization's financial resources to achieve its goals and objectives. It involves making decisions related to the acquisition, allocation, and utilization of funds, as well as managing risks and ensuring compliance with financial regulations.

Review of Literature

The intricacy of strategic financial management, performance evaluation, and investment decision-making processes was studied within organizations [1]. The findings underscore the significance of strategic alignment, innovation, and risk management in

driving organizational success and sustainability. Overall, the researcher contributes to a deeper understanding of strategic financial management practices and provides valuable insights for organizational decision-makers

The complexities of financial strategy management through a qualitative examination and literature review, aiming to illuminate key insights into managing financial performance, investment decisions and strategic approaches within organizations was delved [2]. The primary objective of this study is to provide a comprehensive understanding of financial strategy management by synthesizing existing knowledge and identifying gaps for further exploration. The research contributes theoretical insights by enriching existing frameworks and offers practical implications for managerial practice, guiding organizations in enhancing financial management practices and achieving sustainable competitive advantage

The key aspect of financial management, including financial strategy, performance evaluation and investment decision-making, through a qualitative investigation and comprehensive literature review was explored [3]. The research method involved synthesizing existing literature from diverse sources to identify trends, challenges, and opportunities in financial management practices. The findings highlight the multifaceted nature of financial strategy formulation, emphasizing the importance of aligning strategies with organizational objectives and integrating sustainability principles. Moreover, the study underscores the significance of performance evaluation in assessing organizational effectiveness, with frameworks like the Balanced Scorecard providing valuable tools for comprehensive performance assessment

Objectives of the Study

- To analyze the elements influencing financial management in investments
- To assess the effect of financial management on investment performance.
- To determine the advantages of financial management in relation to investments.
- To offer recommendations for improved investment financial management.

Statement of the Problem

Many people and organisations struggle to manage their money well enough to meet their investing objectives. Many investors make bad investing choices that might result in losses because they lack the information and abilities needed to handle their money well. A variety of risks and uncertainties might affect investments. It can be challenging for investors to sort through the deluge of information from multiple sources and come to well-informed investing selections. A solid grasp of financial management concepts is necessary to address

these issues. Therefore, an exploratory study has been chosen, and "The Impact of Financial Management on Investment Strategies and Outcomes" has been defined as the research problem.

Research Methodology

The research design is basically descriptive. Secondary data served as the study's foundation. Secondary information was gathered from pertinent sources, journals, research reports, websites etc.

Types of Investments

The most popular kinds of investments are as follows:

- ❖ **Stocks:** Stocks are a company's ownership shares. Investing in stock entails purchasing a tiny stake in the business, and investors are entitled to a share of its earnings. Because of the potential for market changes and volatility in their value, stocks are sometimes seen as high-risk, high-reward investments.
- ❖ **Bonds:** In essence, bonds are loans that people give to businesses or the government. The borrower consents to repay the principal amount of the loan at maturity and to pay interest over a certain period of time in exchange for the investment. Although they provide lower returns than stocks, bonds are typically regarded as less hazardous.
- ❖ **Mutual funds:** Mutual funds are investment vehicles that purchase a diverse portfolio of stocks, bonds, and other securities by pooling the money of several individuals. Professional investment managers oversee them and decide on investments for the fund's shareholders. Although they have costs and fees, mutual funds provide professional management and diversification.
- ❖ **Exchange-traded funds (ETFs):** Funds and exchange-traded funds (ETFs) are comparable, except ETFs trade on an exchange like stocks. They provide the same advantages as mutual funds, such as expert management and diversification, but they are typically less expensive and more tax-efficient.
- ❖ **Real estate:** Real estate: Investing in real estate is purchasing and holding onto property with the intention of earning capital gains or rental revenue. Although real estate investing can be very profitable, it also entails a large initial outlay of funds and carries risks including market volatility, vacancy rates, and property upkeep expenses.
- ❖ **Alternative investments:** Investing in assets that don't fall under conventional classifications like stocks, bonds, or real estate is known as an alternative investment. Commodities, hedge funds, private equity, and crypto currency are a few examples.

Alternative investments are typically only appropriate for experienced investors and can be high-risk, high-reward ventures.

Importance

When investing, financial management is essential and it enables us to allocate financial resources in an intelligent manner. Creating a thorough financial plan, defining financial objectives, and creating a budget to reach those objectives are all components of effective financial management. The significance of financial management when investing is as follows:

- 1. Evaluate investment opportunities:** With sound money management, people can evaluate investment possibilities according to their financial goals, investment objectives, and risk tolerance. They will be better able to make well-informed investment choices that complement your overall financial strategy thanks to this.
- 2. Manage risk:** There is always some degree of risk associated with investing. Effective money management enables people to recognize and reduce the dangers connected to their investments.
- 3. Monitor performance:** Financial management makes it possible to keep tabs on how investments are doing over time. They can use this information to assist them decide when to acquire, hold, or sell investments.
- 4. Achieve financial goals:** Effective financial management aids in the allocation of financial resources in a manner that optimizes returns and aids in the accomplishment of personal goals.

Impact

Effective financial management is important for investment performance. Following ways in financial management can impact investment performance:

- 1. Risk management:** Financial management helps investors to manage investment risks by identifying, measuring, and mitigating potential risks. Diversification, hedging, and asset allocation are examples of effective risk management techniques that can lower investment return volatility and shield the portfolio from market swings.
- 2. Portfolio optimization:** Financial management also involves optimizing investment portfolios by selecting the most appropriate mix of assets to achieve specific investment goals. Investors can optimize their portfolios to generate higher returns at a given level of risk by diversifying and allocating their assets appropriately.
- 3. Tax planning:** Through efficient tax planning, financial management can also affect the performance of investments. Investors can maximize after-tax earnings and reduce the tax

burden on their investment returns by being aware of the tax ramifications of their choices.

4. **Market timing:** Buying and selling assets in accordance with market circumstances and trends is a component of market timing, which is also influenced by financial management. Investors can increase their investment returns and lower their risk of losses by making well-informed decisions based on market research and analysis.
5. **Cost management:** By reducing the fees and expenses related to investment transactions, good financial management can also aid in the management of investment costs. Investors can lower total investment costs and increase investment returns by choosing inexpensive investment vehicles and negotiating advantageous fee arrangements.

Factors Affecting Financial Management

Following factors can affect financial management for investments, including:

- **Macroeconomic conditions:** The macroeconomic conditions of a country or region, such as economic growth, interest rates, and inflation, can significantly affect how investments are managed financially. These factors can affect investment returns, risk management strategies, and asset allocation decisions.
- **Regulatory policies:** Investment decision-making may also be impacted by regulatory policies and modifications to legislation pertaining to financial management and investments. For instance, modifications to tax legislation may have a big impact on portfolio management and investing methods.
- **Market trends:** Financial management for investments may also be impacted by market trends, such as shifts in consumer behavior or technology breakthroughs. To optimize profits and reduce risks, investors must keep abreast of market developments and modify their investment plans as necessary.
- **Investor behavior:** Investor behavior, including risk tolerance, investment objectives, and investment time horizon, can also have an impact on financial management. Creating investing strategies that fit investors' goals and risk tolerance requires an understanding of their behavior.
- **World events:** World events including pandemics, natural disasters, and political upheavals can also have an impact on investment financial management. Market volatility brought on by these occurrences may have an effect on risk management plans and investment results.

- **Technology:** Technological developments like machine learning and artificial intelligence can potentially have an impact on investment finance management. These technologies have the potential to enhance investment performance and assist investors in making well-informed decisions.

Benefits

Financial management is important in investments, and there are several benefits of effective financial management in investment activities, including:

1. **Maximizing Returns:** Investors can find investment possibilities that minimize risks and maximize rewards with the aid of financial management. Analyzing market patterns, weighing risks and returns, and making well-informed investment decisions that can boost returns are all part of financial management.
2. **Minimizing Risks:** Investors having effective financial management are better able to control and reduce investment-related risks. Financial management entails recognizing, evaluating, and putting policies in place to reduce a variety of risks, including operational, credit, market, and liquidity risks.
3. **Diversification:** By distributing investments among a range of asset types, including stocks, bonds, real estate, and commodities, financial management assists investors in diversifying their holdings. Diversification guarantees that the portfolio is properly balanced and lowers the total risk of the portfolio.
4. **Improved Financial Planning:** Effective investment planning is made possible by financial management, which takes into account an investor's time horizon, risk tolerance, and financial objectives. Investors can make sure that their investments support their long-term financial objectives by creating a carefully considered investment strategy.
5. **Tax Optimization:** Financial management can also help investors in tax planning, which involves identifying tax-efficient investment strategies that can minimize the tax liabilities associated with investments.

Policy Implications

Suggestions for financial management in investments:

- Investors must establish their investment goals prior to placing any investments.
- An individual can maximize returns and lower the risk of losses by investing in a diverse portfolio of assets. Usually, a well-diversified portfolio consists of a variety of stocks, bonds, alternative assets, and real estate.

- Keeping up-to-date with market trends is important for effective financial management. Monitor economic indicators, global events, and changes in laws and regulations that may impact investment.
- Investors should regularly monitor investment portfolios for effective financial management.

Conclusion

The performance and decision-making of investments are significantly influenced by financial management. Efficient financial management techniques can assist investors with risk management, portfolio optimization, tax planning, market timing, and cost control. Having a clear investing plan that fits your risk tolerance and financial objectives is crucial. This involves determining the appropriate asset allocation, diversifying of investments, and regularly monitoring and adjusting portfolio as needed. Understanding the many investing options, including stocks, bonds, mutual funds, and exchange-traded funds, as well as the risks and rewards involved, is also essential. People can improve their chances of reaching their investing goals and building long-term wealth by adhering to good financial management principles.

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Reclaiming Heritage through Magic Realism: Ancestral Legacy and Cultural Identity in Gloria Naylor's *Mama Day*

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ABSTRACT

*Magic realism is a literary genre characterized by the fusion of realistic elements with fantastical or magical ones. In other words, it blends the mundane with the extraordinary, creating a world where the supernatural is presented as an ordinary part of reality. This paper examines Gloria Naylor's novel *Mama Day* as a work of magic realism that intertwines African-American heritage, cultural identity, and ancestral legacy. By following Cocoa's journey back to her ancestral home, the novel addresses themes of identity, trauma, and healing within the African-American experience. Naylor's use of magic realism challenges Western literary conventions and empowers Black women to reclaim their histories through myth and tradition, demonstrating how cultural memory and supernatural elements can reflect and enrich complex social realities.*

Keywords: *Magic Realism, African-American Heritage, Ancestral Legacy, Cultural Identity, Folklore and Myth*

Introduction

The concept of magic realism, originally coined by German art critic Franz Roh in the 1920s, refers to a unique artistic style that emerged during the Weimar Republic, characterized by a method of portraying the enigmas of reality. Although it began as a movement in visual art, magic realism transitioned into literature when it was adopted by Latin American and Caribbean writers in the 1940s. This can be seen in Gloria Naylor's *Linden Hills* and *Mama Day*. In works like *Mama Day*, magic realism serves to reflect cultural beliefs, folklore, and historical contexts, enriching the narrative with layers of meaning that intertwine the ordinary and the supernatural.

Magical Realism

Naylor employs magical realism to challenge western narratives, enabling black women to reclaim their histories through myths and oral traditions. In *Mama Day*, Gloria Naylor effectively uses magical realism to empower black women by addressing historical silences and gaps, redefining knowledge and representation through a matrilineal, mythical or magical system of signification. The novel is set in the fictional island of Willow Springs, which is inhabited by African Americans. The cultural context of the novel is rooted in

African-American heritage, which is largely defined by the experiences of slavery, segregation, and racism. Naylor's use of magic realism allows her to explore the complexities of African-American identity and culture in a way that is both fantastical and grounded in reality. Through a formal device of alternating narrators and perspectives and a double narrative set in completely opposite worlds, New York and the island of Willow Springs, Naylor offers a unique vision of love and magic within an African and American context.

Magical Realism used in *Mama Day*

In Naylor's novel *Mama Day*, the use of magic realism allows the author to explore the complexities of African American identity and the struggles of living in a society that is often harsh and unkind. The novel tells the story of Cocoa, a young woman who returns to her family's ancestral home on the island of Willow Springs, where she faces the hidden truths and mysteries of her family's past.

The community of Willow Springs is defined by the story of Sapphira Wade. Using a legend as the basis of the narrative highlights a key aspect of anthropological magic realism. Sapphira is an African slave woman, whose character is developed through the legend of her killing her former slave master and father to her seven children, in order to hand over the island to his slaves and her descendants in the year 1823, who still own the land in 1999. She is Mama Day's great-grandmother and is known as the mystical "great, great, grandmother" on the Island. She is remembered as a powerful figure in the history of Willow Springs. She is "a true conjure woman: satin black, biscuit cream read as Georgia clay: depending upon which of us takes a mind to her" (3).

Sapphira Wade's supernatural abilities have a profound impact on the novel, reflecting the complex interplay between the rational and mystical. Her supernatural abilities also have a significant impact on Mama Day, who is her great-granddaughter and the protagonist of the novel. Mama Day is a powerful figure in her own right, with the ability to summon lightning with her walking stick and knowledge of herbal cures. Sapphira's legacy serves as a source of inspiration and guidance for Mama Day, reflecting the importance of tradition and heritage in the novel. Mama Day uses her knowledge, inherited from Sapphira to help the people of Willow Springs, often in subtle and mysterious ways.

The unique location of the island adds mystique and sense of isolation, which is a key aspect of its magical nature. The belief in magic is deep-rooted in the island of Willow Springs. The island is also said to be cursed, and many people believe that it is haunted by the spirits of the dead. The island's history and folklore are filled with stories of magic and mysticism, which are part of everyday life on the island.

The weather on Willow Springs Island often mirrors the emotional states of the characters, particularly Cocoa's struggles. This technique is a hallmark of magic realism, where the natural world is intertwined with human experience, reflecting inner turmoil in a tangible way. For instance, when Cocoa is distressed, a storm brews on the island, which symbolizes her inner chaos. "As the clouds darkened and thunder rumbled in the distance, Cocoa felt the weight of her worries pressing down upon her, as if the very sky mirrored her heart's tempest." (45) When Cocoa finds herself in a moment of turmoil, and the weather shifts dramatically, "The winds howled through the trees, a cacophony that echoed Cocoa's own cries for help, as if the island itself was mourning alongside her." (78) This connection between her emotional state and the environment creates a vivid backdrop that enhances the narrative and these incidents illustrate how the external environment reflects internal conflicts, which is a fundamental aspect of magic realism.

Cocoa's transition from New York City to Willow Springs symbolizes a journey between two worlds—the modern and the traditional. Her experiences on the island challenge her perceptions of reality. When Cocoa walks through the woods and begins to see her ancestors, the narrative describes her surroundings in vivid detail, grounding the moment in reality while simultaneously introducing the supernatural. "As she stepped deeper into the woods, the air shimmered, and the faces of her ancestors emerged from the trees, whispering secrets of the past." (45) This line illustrates the seamless integration of the magical with the natural world, inviting readers to experience her awakening to her heritage. "In that moment, the boundaries between past and present dissolved, and she understood that the island was not just a place, but a living memory of those who came before her." (48) In this moment, the narrative explores the theme of magic realism and also highlights the character's transformation and her newfound connection to her cultural identity, suggesting that the island holds a deeper significance beyond its physical existence.

In African religious belief, the term 'living dead' refers to an individual who has experienced physical death but remains alive in the memories of those who knew them. This person is believed to exist simultaneously in the realm of the spirits. In *Mama Day*, the conversation between a living person, Cocoa and a living dead George, reveals the thin line between life and death. The presence of George is felt throughout the novel, but he is never fully seen or understood. For example, when Cocoa is exploring the island, she catches a glimpse of George: "She saw a figure standing in the distance, a figure that seemed to be made of mist and moonlight. He was tall and gaunt, with eyes that seemed to bore into her very soul.... Cocoa felt a shiver run down her spine as the figure vanished into thin air." (156)

At one point, Cocoa reflects, “He’s gone, but he’s still here with me,” (208) highlighting the concept of the living dead. It serves as a gentle reminder that death is not an end, but a doorway to another realm. This aspect of the novel is a prime example of magic realism, as it blends the realistic depiction of Cocoa's life with the supernatural element of George's continued existence. The silent conversation between the dead George and the living Cocoa is significant in the context of African culture, as it points to the African belief in the interconnectedness of the living and the dead.

Ruby, driven by jealousy and unresolved emotions, resorts to magic to inflict illness on Cocoa. As she contemplates her actions, she reflects, “I wanted her to feel the way I felt.” (189). This act highlights the complexities of personal power within the framework of magic realism. In response, Mama Day harnesses her deep-rooted ancestral wisdom to heal Cocoa, stating. This showcases the strength of community ties and cultural traditions. The interplay between Ruby's malicious intent and Mama Day's restorative magic illustrates how the fantastical intertwines with everyday life, emphasizing magic as both a source of conflict and a pathway to healing in their world.

The novel ends with the same corrective voice of Willow Springs back in the present, August 1999, where Mama Day saves Cocoa from a strange illness. She is ready to depart as she has passed her heritage to Cocoa, who has finally found the meaning of peace. The ending of the novel is a magical and symbolic moment that represents the transformation and healing that has taken place in the characters' lives.

As the sun rose over the island, Cocoa felt a sense of peace and tranquillity wash over her. She knew that she had been healed, that she had been given a second chance at life. And as she looked out at the sea, she saw a figure standing on the shore, a figure that seemed to be made of mist and moonlight. It was George, and he was smiling at her. (256)

This incident illustrates the magical and mysterious nature of the ending, and the ways in which the characters have been transformed and healed through their experiences.

Conclusion

The use of magic realism in *Mama Day* allows Naylor to explore the complexities of African American identity and the struggles of living in a society that is often hostile and unforgiving. The incidents from the novel illustrate the magical and mysterious nature of the characters and the world they inhabit, and demonstrate the ways in which magic realism can be used to create a sense of wonder and enchantment that is both captivating and thought provoking.

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Broken Bonds: Exploring the Impact of Maternal Attachment in Gail Honeyman's *Eleanor Oliphant is Completely Fine*

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ABSTRACT

This paper analyses the negative effects of attachment theory in Gail Honeyman's Eleanor Oliphant is Completely Fine, with a particular emphasis on the protagonist's broken relationship with her mother. Eleanor's journey is an exploration of attachment theory, which states that early bonds with caregivers shape an individual's emotional health and interpersonal relationships. Eleanor has a difficult time navigating self-worth, trust and social interactions due to her mother's abusive and manipulative behaviour. This study reveals the extent to which a toxic maternal relationship can have a profound effect on a daughter's psychological well-being and how she interacts with others.

Keywords: Attachment Theory, Emotions, Psychology, Dependency

Introduction

Gail Honeyman, the author of the novel *Eleanor Oliphant is Completely Fine*, born and brought up in Stirling, Scotland. This novel delves into the themes of loneliness and personal growth. Gail shared the character Eleanor is not the replica to her real life, but the emotions related to loneliness which is universally relatable. Since the debut novel, *Eleanor Oliphant is Completely Fine* captured the hearts of the readers worldwide, currently she is working on a new novel in a different period and location, promising to the readers to deliver another captivating work.

The novel *Eleanor Oliphant is Completely Fine* is a heartwarming one about a woman who, despite her unusual behavior, manages to find love and connection with the world. The story revolves around the character Eleanor Oliphant, a socially isolated woman who lives a solitary life. She is in her late twenties and early thirties, following some strict routine and spends her weekends alone. She was satisfied with whatever she had and assumed her life was perfectly fine. The carefully constructed world begins to shatter into pieces on the arrival of Raymond in her life. With the help of Raymond, Eleanor starts to overcome the fact and explore the possibility of human connection.

The protagonist Eleanor Oliphant is a finance administration assistant, nearing her 30's she worked at a graphic design company since she graduated from the college. The story begins from Eleanor's isolation state. The only people who visit her apartment are social workers, for a particular interval of six months. The weekend food routine of Eleanor consists of frozen pizza and vodka and the weekly chats with Mummy, every Wednesday are the only means of communication with regular social outlets. Phone calls with Mummy are always painful for Eleanor, feeling unworthy of love and respect.

Attachment Theory

Attachment theory in psychology is a framework that examines the emotional bond between a child and their caregivers and how it affects their development. This theory was developed by British psychologist John Bowlby and it is based on the idea that early relationships with caregivers are critical for a child's social and emotional development. The main idea of the theory is that the emotional bonds one form with their caregivers in infancy affect their relationships later in life. Caregivers play an important role in the development of the child.

According to Britannica, "Attachment theory in developmental psychology, the theory that humans are born with a need to form a close emotional bond with a caregiver and that such a bond will develop during the first six months of a child's life if the caregiver is appropriately responsive". The components of attachment theory provoke different kinds of emotions, in different persons. If any individual lost their caregivers at a young age, the vulnerable infants show their reactions through their actions. Bowlby believed that the absence of the caretakers at the young age of the child builds some will power in the young mind and it also promotes the factor of survival at the very dependent state.

Despondency

Despondency is the second level to promote the survival state of the individual. This is also called the period of despair and this period, who are yet to reunite with the caregivers entered into the next stage, the state of detachment. During this stage, the infant begins to do day to day normal activities without the presence of the caregivers, they become more independent and self-reliant. This emotional detachment with the caregiver creates a new emotional bond with the new caregivers. Bowlby addressed that these reactions, the prolonged separation in the relationships leads to the formation of new romantic pairings.

Mother-daughter Relationship

As attachment theory explains about the early childhood experiences with caregivers especially with mothers and how significantly it shapes the later relationships and the

emotional development of an individual. Eleanor's relationship with her mother was marked by the emotional distance and the detachment from the close bonds. The mother never gave any value towards her emotions, which made her feel unimportant. In relation with Eleanor, she had difficulty in expressing emotions and avoided intimacy on the fear of rejection and abandonment. Mother's neglectful behavior may have led to the fear of abandonment.

Eleanor always bottled up her emotions and often suppressed her feelings; particularly she had trouble forming close relationships with others even with her own mother. Eleanor's present life tracked back to her early childhood experience with her mother. She felt really ashamed and guilty about her inability to rescue her one and only sister, Marianne. When someone asked about her mother, she always said that she prefers not to share about her mother. This can lead to the sense of emotional isolation and difficulty in forming healthy attachments in adulthood. The childhood trauma can disrupt the formation of secure attachments and leave individuals with emotional wounds.

Eleanor's complex relationship with her mother is a powerful illustration of attachment theory. The early childhood experiences had profound implications for her ability to form healthy relationships with society. Eleanor's relationship with her mother was deeply troubled, she was emotionally troubled and abusive in nature, since she had traumatized life, she showed her attitude towards her own children. Eleanor was neglected by her mother and she was the one and only reason for her traumatic event in her childhood which left a long lasting scar in the face of Eleanor. Eleanor expressed her pain as, "I was brought up by a mother who didn't know how to love me. I was always on my own. I had to learn everything myself" (91). Since the mother encouraged the attitude of loneliness and isolation, Eleanor felt disconnected from others and herself. She also instilled some guilt and shame on her own child.

Eleanor thought that she was responsible for the mistakes which were committed by her own mother. The qualities of abusive and neglect in the life of the protagonist led towards the consequences of low self-esteem and emotional disconnection. It is proved that Eleanor's mother is partial towards her children, and there is gender discrimination in that society too. She always wanted a son. She thought if she had a son she could really cope up with society. She expressed with sorrow, "I was cursed with a daughter yet I always wanted a son" (224).

In this novel, Eleanor Oliphant as she got detached with her family, especially with her mom, she was in search of finding peace and harmony in new relationships. Even she didn't know anything about her father, she found pleasure in finding new relationships. Since she did not have any emotional support from her childhood, she was really fond of making

new companions in her life. But her attempt was not a successful one. She found difficulty in framing relationships with others.

Impact of Separation

The strange situation due to the separation leads to negative emotions in the child. The new caregiver of Eleanor Oliphant was Mr. and Mrs. Reed. Her relationship with other children was completely a broken one and she became hysterical and physically violent. Mr and Mrs Reed were much worried about the effects of Eleanor's behaviour on their three children. Rudeness, loud talking, tattling and tendency to blame others were some of the self-protective dynamisms of the insecure children. Eleanor expressed her pain as, "Once I'd dared to think I could belong with other people, but I was wrong" (168). Her first and only boyfriend was Declan. She saw him as the figure of her healing process but during her university days, he became physically abusive and broke her arm twice thus she had to break up with him. Her experience with Declan also caused deep trauma in the inner feelings of Eleanor Oliphant, this would become a reason for her social isolation and difficulty in forming healthy relationships. Her fear of rejection prevented her from trusting people and opening up emotionally.

The early bond formed with the caregivers, especially mom, can continue to influence attachments throughout the life of an individual. When this attachment system is activated fully the child feels safe and secure, these attachment figures protect themselves from harm. If the child senses that the attachment figure, mom, is nearby and responsive to the need, they feel secure and more likely to explore and socialize. If not, it means the child feels distressed and their attachment system also deactivates. Eleanor is the best portrayal of this distressed figure who finds it really hard to socialize and to mingle with other people in her life. Eleanor's chaotic and unpredictable life often controls her emotions, and has led to the distrust of institutions which includes religion.

By rejecting religious beliefs, Eleanor may be able to avoid the emotions associated with faith and spiritual connections may find difficulty in trusting any higher power and rely on others for her emotional support. Her social disconnection and fear of intimacy played a significant role in her rejection of religious beliefs. Eleanor felt really happy about her relationship with Johnnie Lomond and she also stated him as, "husband material ... I'd found the love of my life" (8).

Eleanor's relationship with her mother was very intrinsic. Even though they got separated from the distant, their feelings connected both as a mother and daughter was interconnected together as the common belief of the society. On the contrary Eleanor and her

mother had no intrinsic relation with one another. She was not there in a position to choose her own family. She was really fond and longed to make and create a perfect family structure, when Raymond told her about his family, which consists of father, mother and children. The women like Eleanor always wanted to escape from their painful past and hope for new beginnings. But the trauma of past experiences always affected their life and prevented them from having good relationships with others.

Conclusion

This paper highlights the challenges faced by an individual who struggle with social anxiety and trauma. Her broken relationship with her mother affects her whole life and her relationship with others. At the end of the novel, through the journey of connection, Eleanor discovered solace with others and this is the power of human connection. Thus, Eleanor's journey is a story of hope and redemption. Through the lens of Eleanor Oliphant, a socially awkward woman with a troubled past, the novel delves into the complexities of mental health and importance of empathy.

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Fragmented Identities: The Impact of Colonialism and Opium in Amitav Ghosh's *Smoke and Ashes*

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ABSTRACT

*Post-colonialism examines the enduring effects of colonial rule on societies and how the identities of the colonized are shaped by its impact. In Amitav Ghosh's *Smoke and Ashes*, the opium trade serves as a pivotal theme that reveals the legacies of colonial exploitation and addiction. This study investigates the post-colonial perspective in the text, focusing on the economic and cultural impacts of colonialism on Indian society. The narrative illustrates how colonial practices dehumanized individuals and reinforced harmful stereotypes. By analyzing these themes, this study reveals the lasting consequences of colonialism and underscores the importance of remembering these histories in shaping contemporary identities and struggles.*

Keywords: *post-colonialism, exploitation, colonialism, opium*

Introduction

Post-colonialism is a theory that examines the social, political and economic consequences of colonization. This field of study emerged in the 1960s as scholars from formerly colonized nations began to articulate their experiences. It focuses on the lingering effects of colonialism, analyzing literature, history and culture that were transformed by imperialism. Post-colonialism is closely intertwined with concepts such as Orientalism, developed by Edward Said in his influential text *Orientalism*, Gayatri Spivak's essay "Can the Subaltern Speak?" and Homi K. Bhabha's concept of hybridity. Post-colonial literature often explores how cultural memory is shaped by colonial powers in colonized nations. Additionally, it enables authors to raise questions about what is forgotten and what is remembered, frequently revealing the dominant group's power over marginalized voices.

Amitav Ghosh is an Indian writer born in Kolkata. He is primarily known for his complex narratives that often discuss climate change and colonialism, portraying the realities of Indian life. Ghosh is best known for his *Ibis* Trilogy, which is set against the backdrop of the opium trade. The trilogy consists of three works: *Sea of Poppies* (2008), *River of Smoke*

(2011) and *Flood of Fire* (2015). In this trilogy, the effect of colonialism is depicted through the lens of the opium trade.

Smoke and Ashes: A Writer's Journey Through Opium's Hidden Histories is a travelogue, memoir and a work of non-fiction published in July 2023. The two decades of research involved in writing the *Ibis* Trilogy culminated in this work. The text focuses on the East India Company's role in the opium trade and the exploitation of Indian farmers, which ultimately contributed to global addiction. It serves as a powerful reminder of the forgotten narratives of colonialism and the relationship between India, China and Britain, revealing the dark realities of significant events such as the Opium War, the Sino-Indian War and the American Opioid Crisis.

Post colonialism

Post-colonialism explores the dehumanization of the colonized by the colonizers. Ania Loomba states in her book *Colonialism/Postcolonialism* that “The process of forming a community in the new land necessarily meant unforming or re-forming the communities that existed there already and involved a wide range of practices including trade, plunder, negotiation, warfare, genocide, enslavement and rebellions” (21). In *Smoke and Ashes*, Ghosh examines how the opium trade was used as a tool of colonial control. The forced cultivation of opium replaced traditional farming practices, leading to a loss of agricultural heritage and self-sufficiency. British coerced Indian farmers into cultivating opium instead of food crops, effectively transforming India's agricultural system into a mechanism for British economic interests. For example, farmers in the region of Bihar were compelled to cultivate opium rather than essential crops like rice and sugarcane. Furthermore, the British sought to monopolize the trade in the Malwa region, forcing people to cultivate white poppies instead of red ones. Ghosh references Emdad-ul Haq, who states that “This large-scale conversion of paddy fields into poppy cultivation contributed to a famine in Bengal in 1770” (44). This manipulation of agricultural practices and dehumanization not only devastated local communities but also exemplified the destructive impact of colonialism, leaving lasting scars on the cultural and economic landscape of India. However, economic upliftment is the primary reason behind exploitation.

Post-colonialism in *Smoke and Ashes*

Post-colonialism explores how colonial powers exploited their colonies for economic gain. According to Ania Loomba “Colonialism was the midwife that assisted at the birth of European capitalism, or that without colonial expansion the transition to capitalism could not have taken place in Europe” (23). In *Smoke and Ashes* Ghosh explains that the British used

both India and China as major tools for economic upliftment. Opium was introduced in China as a substitute for bullion payments, as the Chinese had a strong demand for tea. Through this, the British government created its colonial network. India was exploited for its agricultural production, with farmers in states such as Bihar and Uttar Pradesh forced to cultivate opium. The processing took place in factories built in these regions, specifically the opium factories in Ghazipur and Patna. The Indians working in these factories were treated without dignity and offered only menial job opportunities. The finished product was then sent to the port of Guangzhou via the port of Calcutta. This exploitation highlights the fundamental dynamics of post-colonialism, revealing how colonial practices laid the groundwork for modern economic systems at the expense of the colonized.

Bombay largely escaped exploitation by colonizers and experienced upliftment, mainly due to the military power of the Maratha states. Additionally, Bombay's geographical location characterized by mountains, rough terrain and harsh climatic conditions made it difficult to traverse. During the same period, the state of Purvanchal was experiencing defeat. This legacy of colonial impact persists today, with Bihar facing issues such as poor sanitation, health problems and low literacy rates, while Bombay has become one of the wealthiest cities in India. As Ghosh notes, the trade network between Purvanchal and Calcutta significantly contributed to the flourishing of cities like Singapore.

From the perspective of the colonizers, the colonized were viewed through a stereotypical lens. Edward Said states in his text *Orientalism* that the Orient is the cultural mirror of the West and a projection of the West's fantasies and desires, often depicted as exotic, backward and uncivilized. In *Smoke and Ashes*, Indians and Chinese are similarly viewed through these stereotypes. Indians were compelled to engage in smuggling due to poverty and the British monopoly on the opium trade, leading to their characterization as natural thieves. In contrast, the Chinese became addicted due to the high availability of opium rather than demand and they were labeled as naturally addicted to drugs. Meanwhile, the cultivation of the white poppy plant was enforced due to these stereotypes, even though the red poppy plant produced better opium. Ghosh highlights that “not only did Western colonizers succeed in using opium to extract incalculable wealth from Asians, but they were also successful in obscuring their role in the trade by claiming that it had existed from time immemorial because non-white people were by nature prone to addiction and depravity” (46). These stereotypes not only justified colonial exploitation but also continue to influence perceptions of the colonized today, illustrating the enduring legacy of colonialism.

Post-colonialism looks at how the impacts of colonialism still affect societies today, influencing their social, economic and cultural situations. The legacy of the colonial drug issue continues into the modern era with the production of various opium derivatives such as OxyContin, heroin and fentanyl. The American opioid crisis today is reminiscent of the colonial drug addiction in China. The British profited significantly from this trade by employing Canton graduates as smugglers and using indentured laborers from the colonies. Today, substantial profits are generated through the use of technology to produce genetically modified plants and through online sales.

Conclusion

Amitav Ghosh's *Smoke and Ashes* explores the lasting effects of colonialism through the opium trade, highlighting its deep impact on both India and China. Ghosh explains how the forced cultivation of opium altered farming practices and reinforced negative stereotypes, portraying Indians as "natural thieves" and Chinese as "naturally addicted." These perceptions still resonate today, especially in light of the current opioid crisis. By exposing the economic exploitation and loss of dignity imposed by colonial rule, Ghosh emphasizes the importance of remembering these often-overlooked histories. Ultimately, *Smoke and Ashes* reminds us of the need to understand the past to build a fairer future.

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**Harvesting Illusions:
Power, Politics and Fabrication of Reality in *Shoes of the Dead***

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ABSTRACT

The research paper “Harvesting Illusions: Power, Politics and Fabrication of Reality in Shoes of the Dead” critically examines the novel Shoes of the Dead by Kota Neelima about the intersection of agrarian distress and political corruption in contemporary India. It provides a powerful commentary on the socio-political issues that pay towards the suicide of the farmers. It mainly focuses on corruption due to the inclusion of politics in the field of farming. India is an agricultural country where agriculture is considered as the backbone of the Indian economy. However, with industrialisation and urbanisation the farming community is mostly unnoticed. This article mainly focuses on the post-truth tactics in the field of farming where the lines between truth and falsehood are blurred, predominantly in politics. It tends to ignore controversial issues in the field of farming in a way that it never occurred. The usage of methodology in this research paper includes literary and theoretical analysis through close reading of the text. It helps to uncover the deep messages that the author projects through her narratives. Analysing the truth and reality portrayed in the novel explores contemporary issues related to truth, misinformation and subjective realities, particularly in political or social contexts. The findings clearly illustrate that the novel engages with political issues and their role in destroying the environment. The research powerfully evaluates the political issues that shape the life of the farmers and the environment where they live.

Keywords: *Agriculture, Farmers, Politics, Post-truth*

Introduction

In the political sector, post-truth is interpreted as a form of spreading fake news and hiding the truth from the public. The novel *Shoes of the Dead* by Kota Neelima is a political fiction. Kota Neelima is an Indian contemporary author whose works mainly focuses on the issues related to farming and farmers. The research paper tries to examine the post-truth tactics that are used in the field of farming where personal opinions are given more importance by influencing people on what they need to believe. It uses emotive language rather than providing actual evidence to the people. The novel is about Gangiri Bhadra whose

brother committed suicide due to crop failure and the inclusion of politics in denying the compensation money for his death by creating an alternative reality behind his suicide. The research paper also portrays the concept of falsifying statistical data regarding the death of the farmers in order to decline the compensation money. It shed light on the issues that are not spoken in the world outwardly. It shows the inclusion of media behind the false accusations regarding the agrarian crisis. It exposes the true intentions behind the role of institutional powers, which are responsible for the betterment of poor marginal farmers turning against them in order to protect their name and position in the political world. Kota Neelima takes up the courage to expose the problems through her novel *Shoes of the Dead*.

The Turbulence of Power

Post-truth describes a situation where the political world is turned upside down by making distinction between truths and lies. It erodes the trust people have upon the institution of power. According to the Oxford Dictionaries, the term ‘post-truth politics’ was first coined by Steve Tesich in his essay “Nation” published in the year 1992. Post-truth politics can also be termed as post-reality politics. Post-truth became popular especially in the twenty-first century after the introduction of media and technologies. In 2016, it was declared as the international word of the year by the Oxford Dictionaries. Media studies scholar John Hartley uses the term post-truth as the title for a chapter “Journalism in a Post-truth Society,” in his book entitled *The Politics of Pictures*. In the context of politics, post-truth involves spreading misinformation, intentional rumours and fake news. Despite the political parties, government sectors, news media, everyone can spread fake news.

The term post-truth can be applied in many contexts, but scholars and popular commentators grasp it as the only feature of post-truth instead of distinguishing between true or false. In the political sector, post-truth is interpreted as a form of spreading fake news and hiding the truth from the public. The political people often spread fake and false news to manipulate the public. Erosion of truth seems to be a major consequence of post-truth in the political world. Post-truth politics also focuses on ignoring something that can be trivial, controversial by making up in a way that such things never happened. This can happen due to the act of using the power against the powerless and ignoring their problems claiming as though the issue will become more controversial.

The statistical data regarding the problems faced by the people or about their needs is used as actual evidence to indicate the life of people and as a representation of truth which is misused. Without having any sort of concern towards the people who selected them, the politicians either destroy the data regarding a particular problem or they change the data

according to their wellness. This is an indication that for political minds, their position and reputation is more important than the lives of the poor people. They often run for wealth and identity that would keep up their reputation alive and their status without being ruined.

Post-truth politics are skillfully employed in Kota Neelima's novel *Shoes of the Dead*. The novel represents the issue of spreading false news, hiding data and giving misinformation to ruin one's life. The story of the novel alternates between two people Keyur Kashinath, a powerful politician and Gangiri, a poor farmer. Keyur Kashinath is caught with an issue of raising number of farmer's suicide in his constituency, only after when he gets appointed as the MP. In order to protect himself from the turmoil, Keyur calls for an unofficial meeting to discuss about the solutions to stop farmers from committing suicide. Such kind of unofficial meeting is even a clear indication that things are not going in a right way and the truth is to be hidden. When it comes to politics, such an unofficial meeting is not a rare one especially in the context of the novel. In the meeting the members of the suicide committee discuss about the statistical data regarding farmers suicide, providing various reasons for suicide happening in his constituency. Whatever findings said in the meeting are not facts but false lies.

Like some politicians, Keyur spoke better when addressing a small crowd rather than a large crowd. Before we begin, I would like to reiterate what I had mentioned to you all over phone two days ago. This is an informal meeting and I would request you to keep everything said here off the record. He politely repeated No one is to be quoted. (6)

The major issue that gives space for the post-truth politics to come in is the suicides by farmers. It is an undeniable fact that people elect leaders to guide them hoping that all their difficulties will come to an end. They promise the people for a better future, but once they get the position which they were hoping for, all their promises turn into lies. The public without knowing the after effects, give their entire life in the hands of such public servants by casting votes. This is very much evident in the novel *Shoes of the Dead*, where Keyur Kashinath is appointed as the MP of Mityala district. He gets the position as a MP only because of two cunning people Lambodar, the maha sarpanch of Mityala and Durga Das, a member of suicide committee. These two men make the farmers elect Keyur as an MP saying that he will help them to improve their standard of living and to get rid of all their problems regarding farming and to overcome their poverty. They also force the farmers to vote for Keyur by giving them some money.

I would not have identified myself with these people, he gently said. That is not to say I don't need their help because I know I would have not won without the votes these two men got for me, by force and funds. But I would have chosen farmers to be my

allies. Or the labourers on farms, the tenants or any of the underprivileged. In almost every single speech I made, I promised to help the poor and marginalized sections of the society. I need to stand by that promise. I must support the poor labourers, farmers, widows and orphans, Keyur stressed, especially because I was funded by sarpanches and moneylenders. (148-9)

These situations prove that the standards for truth have disappeared. People holding the highest positions in the political sphere report false claims in order to influence public opinion and to increase support. Denying the compensation money will surely make the farmer's family sell their land, the only source of their income in order to close their debts. The politicians claim that the farmers are committing suicide only with an intention to get the compensation money and so by stopping it will prevent the farmers from committing suicide. This indicates how cruelly the farmers are treated and how the things are being hidden without being exposed to the public. Only the things that favour politicians are shown in the media.

Role of Media in Shaping Perception

Though the media is in favour of the political parties, some journalists like Nazar Prabhakar try to showcase the reality by writing articles about what is actually happening to the farmers and who is behind such things. Prabhakar is an indicator of reality who is against the policy of post-truth politics. He tries to portray the reality behind the political world and the suffering that are undergone by the poor marginal farmers. Nazar speaks in favour of the farmers during the committee meeting. He questions the committee members disapproval of suicides as normal deaths just as in a way that normal deaths are being claimed as suicides by the farmers.

Just as you claim that “normal” deaths are being called distress suicides by farmers, Nazar continued, you might have dismissed farmers suicide as “normal” deaths in the past. There is political control in keeping suicide figures low. It disproves debt distress and shows the success of the policies. Figures that make governments look bad are really fudged. (16)

Justice is one of the undeniable things, and to get it Gangiri becomes the member of the suicide committee. This pushes Lambodar and Durga Das into anxiety and they try lots of ways to make Gangiri resign from the committee. They threaten him and his brother's family, but these incidents are not shown in the media to cover up the vices of powerful men like Durga Das and Lambodar. Whatever is shown in the media is fake and has nothing to do with reality. These people even try to kill the farmers in order to protect their name and fame. In

the novel, a man from Allur village is thrown into the lake and so he dies. All such brutalities are not broadcasted in the media. This is not only the condition of the farmers in the novel, but also in the real world, especially regarding the condition of marginal farmers. It is the truth that whatever struggles the farmers undergo is not projected to the real world; whatever suffering the politicians and other people in power give to the poor farmers is not projected; whatever is projected is only the fake news and it is opposite to what really happens. The novel *Shoes of the Dead* is projected as a representation of farmers' sufferings, as the author Kota Neelima presents everything in a courageous way. It brings the problems of farmers into light and shows how the media projects fake news.

I will write the story tonight and put an end to it. Give me one quote and I promise you; the story will protect Gangiri tomorrow. This was, of course, a great story, a real glimpse into the politics of the young generation, the politics of ruthless and arrogance. But it might come too late for Gangiri. Lambodar's plan would have begun by the time the newspaper reached homes of Keyur's political masters in Delhi in the morning. (88)

The concept of post-truth politics is also applied in the act of representing false statistical data by the corporate-serving politicians. To protect politicians from any confusion related to the death of farmers, they create a false record and present it to the public through the media. To protect himself from the political turmoil, Keyur misrepresents the statistical data of farmers suicide thereby constructing a post-truth discourse.

Fabricating Realities

The tactical plan of Lambodar and Durga Das to create an alternate reality is that the increasing number of suicides due to debt distress will be buried with the dead. They are with an intention that the dead farmers cannot come alive and claim that their death is falsified by hiding the reality and it cannot be proven as a death due to distress and harassment from the moneylenders. Post-truth thereby is seen as a rejection of facts and use of lies to shape one's beliefs about reality. Such kind of post-truth discourse in power politics accurately destroys the life of farmers. The post-truth discourse also uses fabricated data as a main source of validity. This is seen in various perspectives in the novel. In the beginning it is seen when Videhi presents a report about the various measures to be taken by the government to decrease the suicide level. It also includes providing investigation report about the number of valid and invalid suicide cases of the farmers. This shows the corruption of data politics regarding post-truth discourse of creating an alternative reality.

Often, fertilizers, pesticides and sprays are applied disproportionately to increase yields. Secondly, subsidies for fertilizers and power should be withdrawn. Thirdly, she

continued the expenditure of farm income is connected to the increase in exposure to urban lifestyles due to television and cinema. Finally, religion is the support system of rural society and spiritual discussions can yield solutions to many problems. (9)

Post-truth also signifies the process of using factual evidence besides falsifying the reality. This significance is seen in the novel as Nazar writes articles and news stories about farmers' suicide, and also about the threatening's given to Gangiri through his news stories. All these references make the novel more factual than a fictional work. From the case studies being discussed in the novel it is elucidated that whatever evidence and incidents portrayed in the novel is not a fictional one rather it is similar to that of things which are happening in real life. Furthermore, the loopholes that the members of the suicide committee use, especially Lambodar and Durga Das in deciding whether the suicide as valid and invalid one is also similar to that of the reality which brings factuality into fictional text. All the corruption and behaviours of the government officials are not a fictional one, everything is fact are things that are actually happening in the society. People in Mityala demanded for a new MP due to the increasing number of farmers suicide in Keyur's constituency which becomes a major threat to his position. Nazar without hesitation presented all the things that are done by the committee members through his news story.

New Delhi: Prominent citizens of Mityala constituency have demanded the resignation of their elected representative, Keyur Kashinath, from Parliament if farmer suicides continue in the constituency. They have called for a fresh election to the Parliamentary seat to be held along with the assembly elections scheduled in six months. Keyur Kashinath, it must be noted, is the son of Vaishnav Kashinath who is known for his decision to quit his post as a minister in the central government, taking responsibility for a mishap that had cost lives. (168-71)

Even though Gangiri takes the path of death at the end of the novel, the appointment of Vadrangi as a new member of the suicide committee representing the farmers is a way of resistance against the post-truth discourse and victory of subjective realities. In the words of Vadrangi "Just wanted to mention that Lambodhar maha sarpanch, the man notorious as apatra Lambodar, today voted for all debt suicide cases as patra or eligible for compensation" (274). These words of Vadrangi proves that post-truth politics is destabilized by Kota Neelima as a way of supporting the subjective realities. The truth that the widows are provided with compensation proves that lies will come to light one day which will act against the power groups, who once dominated the marginalised farmers. The politicians will realise that even

though they try to hide the reality it is impossible in the hands of truth; the subjective realities will become a reason for the downfall of the political world.

Conclusion

The research paper “Harvesting Illusions: Power, Politics and Fabrication of Reality in *Shoes of the Dead*” exposes how institutional powers manipulate the narratives around farmer suicides, distorting reality to serve their own self-serving and corrupt agendas, by presenting a subjective truth that obscures the actual socio-political realities. The novel critiques how those in power such as government officials, corporations or other media outlets construct a false narrative around farmer’s suicide. Inclusion of news stories format in the novel makes the narration of the text more factual than fictional. The novel opens as a battle between the political and the power groups and she concludes the novel in favour of the farmers depicting the fact that there can be only one winner at the end of every battle. The future scope of this research proposes various opportunities for further exploration mainly on the impact of spreading misinformation on society, particularly the influence of post-truth politics in public opinion and government policies.

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Beyond Stereotypes: Redefining Gender Expectations in Louisa May Alcott's *Little Women*

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ABSTRACT

Alcott's Little Women is a quintessential novel that has shaped literary depictions of gender roles and women's experiences in the 19th century. Alcott's story of the four March sisters Meg, Jo, Beth, and Amy explores the complex ways in which women navigated the societal expectations imposed upon them, often torn between the traditional roles of wife and mother and their desires for personal independence and fulfillment. The novel's exploration of gender roles has made it a touchstone in discussions about feminism and the role of women in both literature and society. Through a blend of traditional and subversive portrayals, Alcott offers a multifaceted depiction of womanhood, showing how gender roles shape identity, relationships, and personal aspirations. The objective of the paper entitled "Beyond Stereotypes: Redefining Gender Expectations in Louisa May Alcott's Little Women" is to unearth the gender problems portrayed in the novel and how the characters break the boundaries and come out with flying colours.

Keywords: Gender, family, civil war, sisters

Introduction

Little Women portrays a family affected by the Civil War, focusing on the challenges faced by the women, particularly the aunt and mother of the March siblings, as they strive to maintain their social standing. Mrs. March's compassion is evident throughout the story, and she is admired for serving as a role model, inspiring her daughters to pursue their dreams. The March sisters share a close bond with their neighbour, Laurie, whose friendship with Jo is particularly significant. Laurie plays a key role in connecting Jo and Amy. Jo and Amy are especially captivating, as they are both fearless and determined to pursue what they want, no matter the cost. Their relationships with Laurie and their aunt, along with their playful banter and rivalry, set them apart from the other sisters. Jo's frustration with societal expectations is clear in her actions, while Amy's desire to conform creates a distinct contrast between the two.

Little Women challenges the traditional views of women in 19th-century America. Marmee advises her daughters that they should not focus on finding husbands but instead seek personal fulfillment. Through her actions, Marmee demonstrates that a home can be managed successfully without a man's support, as she does while Mr. March is away at war. While many, like Aunt March, expect young women to seek affluent men, Marmee holds a different view on the value of marriage. According to Adrienne Rich, ". . .fundamental to women's oppression is the assumption that we as a group belong to the 'private' sphere of the home, the hearth, the family, the sexual, the emotional, out of which men emerge as adults to act in the 'public' arena of power, the 'real' world" (qtd. in Haskell 10).

Jo is intriguing as an example of female independence in early American society. She is a tomboy, often reprimanded by her sisters for whistling, using slang, and behaving in unladylike ways. The March sisters represent different aspects of femininity and the varied ways in which women could either embrace or resist traditional gender roles. At the heart of the novel lies the question of what it means to be a woman in a society that defines women's value with their roles within the domestic sphere. While the characters largely conform to the expectations of their time, each sister engages with these gender norms in her own way, revealing the tensions and contradictions inherent in the roles women were expected to play. Through their stories, Alcott engages with contemporary debates about women's place in society, the value of domesticity, and the possibility of female autonomy.

Meg March, the eldest of the sisters, serves as a representation of the traditional womanhood expected of women in the 19th century. Her desire for a life centered around marriage and motherhood reflects the dominant cultural narrative that positioned women as nurturers and caretakers, whose primary role was within the home. At the outset, Meg aspires to live within the bounds of social expectations. Her dreams are largely conventional: she longs for a comfortable home, a loving husband, and the ability to care for her family. In this sense, Meg appears to embrace the ideals of womanhood as defined by her society.

However, Alcott does not present Meg's life as entirely free from tension. While Meg marries John Brooke and settles into a life of domesticity, her internal struggles suggest that even women who seemed to conform to gender roles were not always content within them. Meg's adjustment to married life, particularly her efforts to manage the household on a limited income and balance the demands of marriage with her own desires, highlights the difficulties inherent in fulfilling the ideal of womanhood. Her struggles reveal the pressure placed on women to find fulfillment in the roles of wife and mother, even when these roles are fraught with financial and emotional challenges. Meg invites readers to question whether

traditional womanhood, as defined by domesticity and submission to a husband's authority, could truly offer women the fulfillment they were promised. At the beginning of the novel, Meg says, "I know I do teach those tiresome children nearly all day, when I'm longing to enjoy myself at home" (7).

While Meg's story upholds traditional gender norms, Jo March's narrative offers a counterpoint, presenting an alternative vision of womanhood that resists the confines of domesticity. Jo, the second eldest, is fiercely independent and ambitious, and her rejection of conventional femininity makes her one of the novel's most enduring figures. From the beginning, Jo resists the notion that her future must revolve around marriage and motherhood. She is outspoken, unconventional, and determined to pursue her passion for writing- traits often associated with masculinity in the 19th century. Jo's desire to become a writer and live independently of the domestic sphere represents a challenge to the gender norms of her time, which positioned women's worth about their ability to maintain a home and raise children.

Jo's resistance to traditional gender roles is perhaps most evident in her rejection of marriage as a primary goal. Throughout much of the novel, Jo expresses a desire to remain unmarried, fearing that marriage would limit her independence and curtail her aspirations. Her refusal of Laurie's marriage proposal is a pivotal moment in the novel, as it underscores her commitment to a life that does not conform to societal expectations. Jo's rejection of Laurie can be seen as a rejection of the idea that a woman's primary goal in life should be to secure a husband, and her desire to carve out her own path contrasts with the more traditional aspirations of her sisters.

Both *Pride and Prejudice* and *Little Women* explore gender roles, with Austen focusing on the societal pressure for women to marry for security, while Alcott offers a more progressive view of women's independence and ambitions. While Elizabeth Bennet navigates the limited choices of her time, Jo March challenges traditional roles by pursuing a career and personal fulfillment beyond marriage. Both novels highlight the constraints placed on women, but *Little Women* goes further in depicting a broader range of female aspirations and the possibility of defining one's own path: "It is a truth universally acknowledged that a single man in possession of a good fortune must be in want of a wife" (Austen 44).

However, Jo's eventual marriage to Professor Bhaer complicates this narrative of resistance. In many ways, Jo's marriage seems to suggest a retreat from the independence she initially sought. Some critics have argued that Jo's marriage represents Alcott's capitulation to societal pressure, a concession to the cultural expectation that even the most

unconventional women must eventually settle into the role of wife. Jo's marriage raises important questions about the extent to which women in the 19th century could truly escape the gender roles imposed upon them, and whether autonomy was ultimately compatible with the institution of marriage. When Amy tells Laurie that Mr. Bhaer intends to marry Jo, he responds, "Well, my love, I consider him a trump, in the fullest sense of that expressive word, but I do wish he was a little younger and a good deal richer" (135).

Beth March, the third sister, represents a more passive embodiment of traditional femininity, characterized by selflessness, nurturing, and submission. Throughout the novel, Beth is portrayed as the most virtuous and self-sacrificing of the sisters, embodying the ideal of the "angel in the house" that was prevalent in Victorian society. Beth's life revolves around caring for her family, particularly her parents, and she never expresses any desire for a life outside the home. Her quiet acceptance of her role as a caretaker can be interpreted as a reflection of the societal expectation that women should find fulfillment in service to others, particularly their families.

Beth's character, however, raises complex questions about the cost of conforming to such rigid ideals of femininity. Her passivity and selflessness, while initially presented as virtues, ultimately lead to her demise. Beth's death can be seen as a symbol of the dangers of idealizing a form of womanhood that requires women to completely subsume their own desires and needs to those of others. In this sense, Beth functions as both an embodiment and a critique of the gender roles that defined women's lives in the 19th century. Her tragic end suggests that the ideal of womanhood as self-sacrifice is unsustainable and that the demands placed on women to be endlessly nurturing and selfless could have devastating consequences.

Amy March, the youngest of the sisters, offers a more complex negotiation of traditional gender roles, blending ambition with an acceptance of conventional femininity. While Amy initially appears shallow and materialistic, her character undergoes significant growth over the course of the novel. Amy's early desire for wealth and status reflects the societal pressure on women to marry well in order to secure their social and financial standing. Simone de Beauvoir opines

Marriage was deemed necessary in traditional society to procreate and so that the man could keep track of his progeny, in the process of which, the woman become man's property. To seal that transaction, a husband provided the wife a roof over her head, money, and social security. The wife, in return, provided him and his family with heirs and care. As the world changed and women became less dependent on the

financial and social security that came with marriage, some people began to opt for marriages based on love, mutual respect, and shared values.

However, as she matures, Amy develops a more nuanced understanding of what it means to be a woman in her society, balancing her personal ambitions with the expectations placed upon her. While Amy attempted every branch of art, she could not become a great artist. One of her weaknesses was a desire to move in ‘our best society’. Amy says, “I should like to take them for a drive to the places they want to see, a row on the river, perhaps, and make a little artistic fete for them” (90). Amy’s pursuit of art as a means of self-expression demonstrates her desire to engage in a creative life, but unlike Jo, she does not entirely reject the traditional roles of wife and mother. Amy’s marriage to Laurie, while practical in some ways, also represents a union based on mutual respect and affection. Redefining gender expectations involves challenging traditional roles and embracing the freedom to pursue personal identity, ambition, and fulfillment beyond societal norms.

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Reclaiming Voice through Traumatic Narratives: A Psychoanalytic Exploration of *The Way I Used to Be*

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ABSTRACT

*This paper explores the profound effects of sexual abuse on the protagonist, Eden, in Amber Smith's novel *The Way I Used to Be*. Through a psychoanalytic lens, this study examines Eden's trauma, coping mechanisms, and complex recovery process. The novel illustrates the devastating consequences of trauma on Eden's identity, relationships, and worldview. This research highlights the importance of supportive networks, self-care, and boundary-setting in the healing process. By examining Eden's journey, this analysis sheds light on the non-linear nature of trauma recovery and the resilience required to reclaim control.*

Keywords: *Sexual Abuse, Trauma, psychoanalysis, Identity Formation, Resilience.*

Introduction

Psychological trauma results from severely distressing events beyond the normal human experience, such as violence, rape, terrorist attacks, natural disasters, accidents, or significant losses. Trauma impacts individuals differently, influenced by factors like support networks, coping mechanisms, and pre-existing mental health conditions. Psychoanalytic theory deals with the function and development of the human mind. Psychoanalysis, founded by Sigmund Freud, believes that a person can be healed by making their mind unconscious during the healing period. Psychoanalysis in literature serves as a means to analyze a literary work psychologically. The uniqueness of Freud's exploration lies in his linking the unconscious with its decisive role in human life. The unconscious is the storage of traumatic experiences, emotions, unresolved conflicts, recognized desires, fears, and so on.

Psychoanalytic Reading: *The Way I Used To Be* by Amber Smith is a novel that tells about the traumatic experience of the protagonist, Eden McCrorey. A fourteen year old girl, Eden had been raped by her brother's friend while she was sleeping. It tells the story of the impact of sexual abuse she experienced. Besides that, it also demonstrates the strength of Eden as she navigates unacceptable disappointment and pain during her adolescence. This includes

her first love and first heartbreak, the breakdown and eventual rebuilding of friendships, and the journey of embracing her inner strength to survive pain and trauma. These experiences reveal the resilience she has concealed within her heart. In *The Way I Used To Be*, one prominent cause of trauma experienced by Eden's character is the continuous sexual abuse by Kevin. In the incident of sexual abuse, Eden's trauma is compounded not only by the abuse itself but also by Kevin's subsequent threats, leading her to confront the harsh reality.

I'm scared to look. But there they are: my days-of-the-week underwear in a ball on the floor. They were my Tuesdays, even though it was Saturday, because, well, who would ever know anyway? That's what I was thinking when I put them on yesterday. And now I know, for sure, it happened. It actually happened. And this pain in the center of my body, the depths of my insides, restarts its torture as if on cue. I throw the covers off. Kneecap-shaped bruises line my arms, my hips, my thighs. And the blood on the sheets, the comforter, my legs. (3)

Eden's family treats Kevin very well, without knowing what he has done to Eden. Kevin even uses all the things that belong to Eden, to make her disgusted, for what has been done to her. Kevin's presence is not only in every corner of her house but also imprints on her body and memory. Eden expects her brother to be more concerned, so that she can tell the abuse that Kevin has done. Later, Eden hopes to get defense from Caelin, who has always protected her well. At least by getting defense from Caelin, Eden can feel calmer, and her stress can be reduced. Her brother's protection helps her regain her sense of security and handle the situation better.

Eden hated her body and her own life. "My body is a torture chamber. It's a fucking crime scene. Hideous things have happened here, it's nothing to talk about, nothing to comment on, not out loud. Not ever. I won't hear it. I can't."(109-110). The line vividly depicts Eden's trauma with intense imagery, effectively conveying their suffering and isolation. Eden uses Josh as an escape to cover up the bad events with Kevin. "And suddenly the thought of having someone else there in place of him is something I required-wanted-needed, in the most severe of ways. And I don't really care who, anyone else at all will do. This guy, Josh, he's good enough. He did, after all, pick me a weed" (92). The above lines illustrate how Eden chooses Josh to replace Kevin's place in her mind.

Eden thinks that the memories of Kevin can be erased from her mind by spending time with other people. She made Josh as her friend, who had given her a dandelion. Eden feels the need to escape fantasy with someone else to take Kevin's place. Eden had sexual relations with fifteen different men. "I've been with fifteen different guys-sometimes it seems

like too many; other times, it seems like not nearly enough. But each one takes me just a little farther away. I'm so far now" (235). These relationships are used by Eden to cover up the former rape committed by Kevin.

Emotional Pain

Eden's emotional pain reaches a boiling point, prompting her to seek refuge in harmful habits. She turns to substance abuse, using alcohol and drugs to numb her emotions and temporarily escape the trauma. She also engages in self-destructive behaviours, such as reckless relationships and dangerous activities, in an attempt to distract herself from her emotional agony. Meanwhile, Eden's psychological struggles deepen, manifesting as dissociation and disconnection from her own thoughts, feelings, and bodily sensations. She experiences memory lapses and flashbacks, reliving the traumatic experience in vivid and terrifying detail. As her sense of identity begins to unravel, Eden faces an existential crisis, questioning her own values, beliefs, and sense of self. Her trust issues become pronounced, making it difficult for her to form and maintain healthy relationships or feel safe in her own skin.

Eden's feelings were a complex web of emotions, a tangled mess of pain, fear, and uncertainty. She felt like she was drowning in a sea of trauma, unable to find a lifeline to cling to. The rape had stolen her sense of security, leaving her feeling exposed and vulnerable. Eden's intense hatred serves as a coping mechanism for the pain she feels, indicating her struggle to process the feelings of hurt, betrayal, or loss. Her emotions often overwhelm her, leaving little room for other feelings. This pervasive resentment dominates her life, hindering her healing and fuelling her helplessness and frustration. Despite her efforts, Eden feels trapped, unable to escape this cycle of hatred.

The initial stages of Eden's journey are marked by isolation, but she gradually allows herself to build new relationships. Her friendship with Alex, a fellow art student, provides her a safe space to share her experiences without judgment. He offers a listening ear and unwavering support, reminding her that she is not alone in her struggles.

Recovering from trauma includes both emotional restoration and psychological growth. Eden tries negative ways to ease the burden of her trauma, "I bring the bottle to my mouth and finish off half the beer in one gulp" (189). Drinking beer became one of Eden's escape places to reduce the fear and stress caused by the trauma of sexual abuse. Eden heals from trauma through self-care and boundary-setting. She avoids dwelling on past pain, focuses on the present, and shields herself from toxic people who might drain her mental and emotional energy.

Conclusion

Throughout the novel, Eden's trauma shapes her relationships and worldview, pushing her into a state of isolation, where the overwhelming pain makes it nearly impossible to express what she feels to those around her. Her sense of safety, identity, and ability to trust others is shattered, and she is left grappling with intense feelings of shame, anger, and confusion. Eden's journey reflects the difficult reality of living with trauma, where healing is not a linear process but rather one fraught with setbacks, uncertainty, and emotional upheaval.

Recognizing the depth of Eden's suffering, everyone begins to see the small steps she takes towards healing. Though Eden remains deeply affected by the trauma, her ability to confront and feel the intensity of her emotions signals the beginning of her journey toward healing. The scars of her trauma will not fade quickly, but the author emphasizes the possibility of slowly reclaiming control, even as Eden navigates the long and complex process of recovery.

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Exploring Isolation and Bizarre Voyages in Morten Tyldum's *Passengers*

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ABSTRACT

Morten Tyldum's Passenger provides a narrative space for exploring themes like isolation, exploration, bizarre psyche and epic voyages within the context of travel writing narratives, "Travel writing is examined as a metaphor for imagination, subjectivity and representation, and its influence on other literary genres" (Zilcosky, 2008). This term paper looks deeper into the multifaceted layers of the film, showing the portrayal of isolation and the human psyche in the vast wild environment. Through the analysis of characters, dynamics, setting, and thematic elements, the paper aims to showcase how the movie taken for study navigates the psychological aspect of loneliness and discovery. The study emphasises the value of human connection in the face of isolation and the attraction of exploration by looking at the experiences of the characters and the existential issues they encounter in the expanse of space and unfamiliarity of travelling into the unknown.

Keywords: *bizarre voyage, travel narrative, space.*

Introduction

Morten Tyldum's *Passengers* gives the essence of exploration, isolation, and the human psyche within the vastness of space. The movie provides a captivating narrative space, related to classic travelogues, where characters go on epic voyages, facing the challenges of solitude and the search for purpose. This term paper looks into the complex layers of the film, analysing its portrayal of isolation and the human psyche through the lens of travel writing narratives.

"The travel narrative metaphor is a powerful tool for understanding personal life and mental development."(K. Mikkonen, 2007). By examining characters, dynamics, settings, and thematic elements, this paper aims to explain how the movie, "Passengers" shows the psychological complexities of loneliness and discovery, providing a wider view into the existential bizarre that arises during long-distance space travel.

Movie and Fiction

The movie presents a modern interpretation of classic travelogues, using the context of space travel to explore themes of exploration, isolation, and self-discovery. It tells the story of Jim and Aurora, two passengers aboard the spaceship *Avalon*, who are awakened from hibernation decades too early on their journey to a distant colony. Their situation, trapped on a massive spaceship with no way to return to hibernation or reach their destination during their lifetimes, mirrors the experiences of early explorers. Like those adventurers, they are thrust into an unfamiliar and vast environment, far removed from the familiar, and forced to adapt to the challenges and opportunities their isolation provides.

Classic travelogues often chronicled journeys into unknown territories, documenting not just the physical landscapes encountered but also the psychological and emotional journeys of the travellers. This movie builds on that tradition, but instead of the earthly terrains of deserts, oceans, or mountains, it uses the infinite expanse of space. The ship *Avalon* becomes a microcosm for the human experience of exploration, a confined and self-contained world drifting through the uncharted universe. Jim and Aurora's story reflects the shift described by M. Pfister, where "travelogue narratives have evolved from accounts of journeys to more self-reflective forms of self-writing and self-staging" (2019). Their journey is not just about moving through space but about navigating the depths of their own psyches and emotions.

The psychological impact of isolation is a central theme in the movie. Early in their awakening, Jim and Aurora experience the vastness of their loneliness. With over 5,000 other passengers and crew members still in hibernation, they are surrounded by people yet utterly alone. Their sense of isolation is heightened by the knowledge that the ship is on a 120-year journey to its destination, leaving them no hope of outside help or eventual escape. This mirrors the feelings of solitude and alienation described by explorers and travel writers throughout history. As Svetlana Haraz points out "Solitude can enhance resilience by providing cognitive processing and problem-solving capacity, but excessive isolation can have negative effects" (2023).

At first, the solitude forces both characters to confront their situation in different ways. Jim, who wakes up first, experiences the crushing weight of being alone for over a year before Aurora's hibernation pod malfunctions which is deliberately tampered with by Jim, a morally complex decision. During that time, he grapples with intense loneliness, which leads to despair and even thoughts of ending his life. His decision to awaken Aurora, while ethically questionable, is born from his overwhelming need for human connection,

highlighting the psychological toll of isolation. Aurora's initial response to her awakening is one of confusion and disbelief. As she learns the truth, her emotions evolve from gratitude to anger, and she must navigate feelings of betrayal alongside the existential reality of their shared predicament.

As the two begin to interact, their relationship becomes a central part of their journey. Their companionship provides moments of relief from the burden of their isolation, allowing them to find joy and purpose in each other's company. These interactions reflect the duality of solitude that Haraz describes: while solitude can foster introspection and problem-solving, the lack of connection can be deeply damaging. The bond between Jim and Aurora becomes both a lifeline and a source of tension, as they must reconcile their individual needs and ethical dilemmas while navigating their shared fate.

The movie also explores the concept of purpose and meaning in the face of overwhelming odds. Both Jim and Aurora had boarded the *Avalon* with dreams of starting fresh lives on a new colony. Their premature awakening shatters those dreams, leaving them to grapple with questions of what their lives mean now. This existential crisis drives much of the narrative, as both characters attempt to find purpose in their current circumstances. Jim, a mechanic by trade, pours his energy into repairing and maintaining the ship. Aurora, a writer, turns to documenting their experiences and reflecting on what it means to live under such unique circumstances. Together, they face challenges that test their resilience, from mechanical failures on the ship to the emotional strain of their isolation.

Ethical and existential questions are woven throughout their journey. Jim's choice to awaken Aurora raises issues of morality, agency, and the lengths to which humans will go to avoid loneliness. For Aurora, the revelation of Jim's actions forces her to confront questions of trust, forgiveness, and survival. The movie's exploration of these dilemmas underscores the complexity of human relationships and the moral ambiguities that arise in extreme situations. Their experiences also highlight the broader theme of adaptation, how humans can adjust to even the most challenging circumstances and find ways to create meaning and purpose.

The ship *Avalon* itself becomes a metaphor for their journey. As a self-contained ecosystem traveling through the void, it mirrors the human condition: a fragile existence in a vast and indifferent universe. The ship's malfunctions and the characters' efforts to repair it symbolize the delicate balance required to maintain life and hope in the face of adversity. The physical challenges they face, fixing the ship's systems, surviving near-death experiences,

and preserving the lives of the other passengers, parallel their emotional struggles. Each challenge forces them to confront their fears and grow as individuals and as a pair.

Ultimately, the movie shows the resilience of the human spirit. Despite the profound losses and challenges they face, Jim and Aurora find ways to live in the moment and embrace their reality. This acceptance does not come easily; it is the result of emotional growth, mutual understanding, and a shared determination to make the best of their circumstances. Their journey becomes one of self-discovery and salvation, not in the traditional sense of escaping their predicament but in finding peace within it. Their story reminds viewers that even in the most isolating and hopeless scenarios, humans have the capacity to adapt, connect, and create meaning.

Conclusion

The movie reimagines the classic travelogue for a modern audience, using the lens of space travel to explore timeless themes of exploration, isolation, and human resilience. By focusing on the psychological and emotional journeys of its protagonists, it shifts the travelogue's focus from the external to the internal, aligning with M.P. Fister's observation about the evolution of travel narratives. The story of Jim and Aurora is a testament to the complexity of human relationships and the enduring quest for meaning in the face of adversity. Their journey aboard the *Avalon* is not just a physical voyage through space but a profound exploration of what it means to be human in an unforgiving universe. This combination of physical and emotional exploration makes the movie a compelling and thought-provoking reflection on the nature of travel, isolation, and the search for purpose.

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From Silence to Speech: Animated Videos an Effective Tool for ESL Learners

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ABSTRACT

In India, proficient English speakers can be numbered. Communication plays a major role in the discipline of language learning. The ESL learners gain knowledge on LSRW skills for years yet they are inept with communication skills which is vital for an individual at the present. ESL classrooms are in dire need of new methods to assist the learners in the learning process. The Needs of the learners differ from generation to generation, only if a teacher is updated and copes up with the interest of the young learners' mindset by filling the generation gap between them, they can make a great impact in the teaching and learning process. Language teachers incorporate new teaching tools and techniques to motivate, support and engage the learners to use the language. This paper tries to highlight the importance of materials and material production. Similarly, it shares about using animated videos available on YouTube as a material in the language classroom for better learning.

Keywords: *Materials, Material Production, Animated Videos, Communication Skill, Activities*

Introduction

English occupies a substantial position all over the world, hence developing its communication skills is essential. In the modern era, being effective communicators is the most demanded skill pertaining to any discipline or profession. The term 'Communication' is complex as it deals with conveying the thoughts and emotions of a person with the same feel and content. Even a small error in communication creates a massive drift among people. In India, though the learners are familiar with English from their primary level they are vulnerable in their communication skills. Hence numerous teaching materials and tools are experimented in the language classes to make the teaching-learning process more engaging, entertaining and interesting.

Videos can be considered as the most entertaining and stimulating tool in a language classroom. As authentic video materials as movies, films, operas and songs aids learners' in creating an interesting, challenging, fun and entertaining atmosphere in the classrooms for

developing themselves. Further a language teacher encourages the learners to deconstruct, decode and criticize videos to extend their in-depth thinking and critical views. English movies provide direct, vivid and realistic scenarios to understand the culture and society of English-speaking countries which help the learners to use the language appropriately. Classes with videos has advantages with its sound effects, vivid scenes, dialogues between characters backed up by visual effects to suffice learners' boredom. Time duration acts as an impediment while teaching through video materials and to avoid these teachers opt for short videos. Teachers could begin with aesthetic appreciation, introduction and background of the clip and analyze the plot, theme, genre, main characters and its style of narration. The techniques employed in the film such as pictures, scenes, acoustics, and montage can also be discussed depending upon the time duration of the classes.

General Objectives

- Communication skills of the learners will be enhanced
- The learners will be encouraged to actively participate in the classroom activities

Specific Objectives

The study will help the learners

- to enhance their listening and speaking skills
- to kindle their 21st century skills like critical thinking, creativity, collaboration, cultural competency, Information and media literacy, etc
- to probe through their characters and values
- to engage them in individual and group activities
- to combine education and entertainment for an ecstatic classroom atmosphere
- to reduce their anxiety towards English
- to express their thoughts with simple words and sentences

Need for the study

English is a second official language in India used as a medium of instruction in Government and Educational sectors but Indians still struggle to communicate. This research tries to make use of animated videos as a tool and help the learners become effective communicators.

Review of Literature

Materials support teachers to begin a lesson interesting and to develop the skills of the learners. Tomlinson in the article "Materials Development" (2001) states that "materials achieve impact through novelty, variety, attractive presentation, appealing content and achievable challenge". Materials achieve impact on learners by instigating their curiosity and

interest. It acts as a great support for both the teachers and learners in the process of learning. Animated Videos incorporated as material in language classroom assists learners in acquiring both the language and the culture. Meanwhile it also creates an entertaining, causal and serene atmosphere with its visual effects. Learners' find video lessons more interesting, challenging, and stimulating for developing themselves. And it effortlessly produces better meaning to any context with illustration through pictures and conveys the meaning of countless words and emotions.

Zhaogang Wang (2014) in his article "An Analysis on the Use of Video Materials in College English Teaching in China" exhibits the aims of using video materials in EFL classrooms and the advantages of it on the basis of teaching principles, strategies and techniques. The preparation of various activities for the classes becomes a must as it helps the teacher to take full advantage of the video materials and the learners. Importantly, prior focus should be given on the selection of the movie/ video. With clear procedure and proper goals, the teacher can use movies as an aid for teaching. This can improve the language competence of the learners with the cultural background and aesthetic value. The pros and cons of using videos as teaching aid are also discussed.

Ashvini Joshi (2012) in her article "Multimedia: A Technique in Teaching Process in the Classrooms" brings out multimedia as one of the major aids through which a language learner can develop his language skills as it paves way for interaction and fun between teachers and learners. It mainly focuses on the impact of multimedia in the classroom and the effect of computers and the internet. The interaction with multimedia gives a wider knowledge on the academic vocabulary and language structure. The technology combined with teaching serve as a successful teaching method. Use of Multimedia is a successful way of effective teaching but the point whether it becomes effective or not is in the hands of the teacher.

Solanki D. Shyamlee (2012) in her article "Use of Technology in English Language Teaching and Learning": An Analysis" opines the importance of technology in language teaching. As the modern society is filled with gadgets, technology never deteriorates to provoke interest among the learners for studies, communication and to understand the culture. Meanwhile it also creates problems such as restriction of thinking capacity and loss of communication by over using the gadgets. This paper aims to make the language teachers aware of the ways in which technological aids can be used and the processes that mostly help the learners to motivate themselves to use the language and bring out effective results. Through these technological aids, the classes would be more learner centric.

Shannon Kelly Brown (2010) in his article “Popular films in the EFL classroom: Study of methodology” explores the impact of English-Speaking foreign films in the EFL classroom for teaching vocabulary along with culture to the Japan University Freshmen. It mainly aims to identify vocabulary in connection with the culture and the ways to improve them. The study concludes that teaching culture is not as easy as teaching vocabulary to the learners. Similarly, Ismail Cakir (2006) in his article “The Use of Video as an Audio- Visual Material in Foreign Language Teaching Classroom” has also pointed out the use of video for language teaching with its effective authentic language input.

Materials

Material is an umbrella term that provides diverse concepts in various fields. In teaching, material can be of any form that assists in the learning process. Materials include textbooks, audio and videotapes, maps, graphs, pictures, newspapers, etc. that serve the purpose of teaching and learning. Influential and meaningful teaching materials are assets to teachers and learners. A material prompts the learners to utilize the provided opportunities to communicate in the target language and engage them with content and scope in developing their language. Videos and movie clips as materials assist in developing the communicative competence of an individual. Through these, the learners are made to feel at ease to use simple sentences in the target language and accomplish their tasks.

Types of Materials

Materials are progressed based on the curriculum aims of an institution or an organization in feasible forms concerned with their financial and technological sustainability in the path of developing the learners. Materials are mainly classified as:

- printed materials – books, workbooks, worksheets;
- non-printed materials – cassette, CDs, videos, computer-based sources;
- materials comprising both printed and non-printed sources – self access materials, materials on the internet and
- authentic materials. (materials that are not prepared for classroom purposes such as newspapers, magazines and TV broadcasts).

Aims of Materials

Materials aim at enhancing the learners’ knowledge and provide an immense support to the teachers to stimulate responses from the learners. It prompts the learners to utilize the provided opportunities to communicate in the target language. Materials in language teaching aims:

- to have an impact on the learners and boost their self-confidence

- to be relevant and supportive for the learners
- to expose the authentic usage of the target language
- to communicate in target language when opportunities genuinely arise
- to obtain new knowledge with curiosity
- to provoke intellectual, emotional, creative and aesthetic sense of the learners

Material Production

Material production refers to the production of new materials or modifying the existing materials depending upon the needs of the learners. Tomlinson (2001) states material development refers to anything which is done by writers, teachers or learners to provide sources of target language as input. According to Nunan (1988), Material development is dealing with the selection, adaptation and creation of teaching materials. Materials designed with solicitude contribute valuable information for self – evaluation that reflects learners’ usage of the target language and their development in the forms and skills of the language. The created materials should yield circumstances where learners interact with each other and engage them in situations outside the classroom. It should be interesting and attractive in promoting curiosity among the learners. The materials should focus on situations where the learners interact with respect to meaning, pronunciation, form, tone and skill of the language.

Principles of Material design

According to Sathya (2017) in her thesis “The Impact of Interactive Course Materials in enhancing English communication skills of the tertiary level learners” opines the principle of material design as follows:

- language learning must be contextualized
- language used is authentic and realistic
- materials must engage the learners
- classroom materials seek audio-visual materials
- materials must deal with spoken and written language
- effective learning material fosters learner autonomy
- materials must be flexible enough to allow individual and contextual differences
- language needs of the learners must engage effectively and cognitively

Materials chosen for the study

The researcher has chosen two animated videos titled “Snack Attack” and “Dustin” from YouTube platform. “Snack Attack” was written and directed by Andrew Cadelago in 2015. The video is about an old lady and a teenager waiting to board the train; meanwhile they engage in a cynical clash over their snack. It is a crisp, value based comical content. It

makes the audience wonder about the perception and prediction one has on other people, similarly questions people's decision making, and problem-solving skills.

“Dustin” is another animated video that revolves around a pug and his new roommate, an automatic cleaning robot. It discloses their love and hate relationship, making people wonder about human life. It was written by Michael Fritzsche, Kristina Jaegar, Andreas Tetz and Nadine Utz. and directed by Kristina Jaeger in 2020. This video discusses values like love, bond, friendship, etc.

These animated videos help the learners to have an easy and clear understanding of the content promoting them to engage in conversations and usage of the language. The chosen videos create an entertaining atmosphere and also a new learning environment. Through these videos the learners not only develop their language skills but also are inculcated with values that are essential for life as videos generally act as an easy and fastest tool to convey the content to the learners.

Description of the Cohorts

The study is focused on the tertiary level students of Holy Cross College, Nagercoil. 64% of the learners are from rural backgrounds. Though they are familiar with English they struggle to use the language or to engage in conversations.

Methodology

A Task Based Language Teaching approach is employed for the classes. Animated Videos “Snack Attack” and “Dustin” are used as teaching materials in the classes and tasks are formed based on the content. The animated video “Snack Attack” through a story of a pug ponders on the human-animal relationships, emotional bond, companionship, rivalry and robots. “Snack Attack” is about the misunderstanding between an elderly woman and a young man provoking the generational gap, human bonding, lack of communication, etc. Both these videos reflect the gap of modern society with the tremendous growth in technology relating to networks and gadgets. It reflects among the youngsters as they transform as tech savvy and alienating themselves from human emotions and bonding.

The tasks assigned to the learners stimulate their Intelligence Quotient, Emotional Quotient and Social Quotient while using the target language. The learners are given an introduction on the videos and a brainstorming session is followed to check the understanding potential. The videos are paused at regular intervals to raise the learners' curiosity and to interpret and guess what its twist or climax is. The learners are engaged in individual or group activities through which they gradually utilize and practice to effectively engage in conversations.

Skills Focused

No skill can be taught in isolation. In these lessons, mainly listening and speaking skills along with other 21st century language skills are focused. Further the learners are motivated to listen for the specific information and to understand the speaker's ideas, opinions, and suggestions. They speak to describe the events that happened, they discuss and express their thoughts, concerns and opinions.

Procedure

The animated videos "Snack Attack" and "Dustin" are watched by the learners twice or thrice on two different days. A quick brainstorming session after each video is carried to test the understanding of the learners. The teacher poses 'wh' questions on the content of the video and similar topics are discussed among the learners. Activities such as role play, discussion, debate, etc. are conducted with reference to the content of the video. They actively utilize the preparation time and use adequate words to express their thoughts and emotions without hesitation.

Findings

The findings of the study are listed below:

- Learners were stimulated and motivated through the animated videos extending the attention span in the classroom
- Learners were confident to indulge in brainstorming activities after prior encouragement and understanding of the content
- The learners were cooperative and innovative as they indulge themselves in role play, discussion and debate activities within a limited time span
- A more relaxed and entertaining atmosphere was created among the learners.
- Learners were trained to work individually and in groups
- Providing space and suggestion for better communication increased the language skills of the learners
- Learners 21st century skills were developed through the activities
- Critical Thinking Skills were fostered by examining the misunderstanding in "Snack Attack" and questioning the events unfolding in "Dustin"
- Creativity skills were honed through verbal conversations in role play activity
- Problem Solving and Information Gap skills were inculcated by analyzing the plot of the animated videos, discussing the different perspectives with individual thoughts
- The general and specific objectives of the research were fulfilled by making the learners participate in the activity and enabling them to communicate in the target language

Conclusion

Communication is a continuous process involving the purpose of informing, expressing and influencing. Teachers have to be extremely creative and lively with materials that are to be used in the classroom. When materials are new and fascinating along with appreciable activities, the learners become more active and participative in class. Meanwhile, learners' lack of confidence and fear of ridicule with time restrictions and in depth insights on the video acts as the major barriers in their communication. Further selecting and screening informative and relatable materials in the classroom by grabbing and withholding the attention of learners without any intervention becomes a major turmoil. Apart from these limitations, videos promote motivation and passion in an individual to excel. Hence, for developing the communication competence it is mandatory to participate in interactions and activities. This research tries to enable the learners as good communicators of English with the aid of animated videos as materials. The learners do not exhibit a massive transformation in communicating but gradual progress is visible. The learners utilize the given opportunities and communicate without hesitation.

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Reimagining Ecology and Human Survival: An Ecocritical Exploration of Paolo Bacigalupi's Works

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ABSTRACT

*Ecocriticism offers a vital lens for examining the intricate connections between literature, human survival, and the natural environment. This article delves into the ecocritical themes in Paolo Bacigalupi's novels *The Windup Girl* and *The Water Knife*, which explore dystopian futures shaped by environmental degradation, corporate greed, and resource scarcity. Bacigalupi's speculative worlds depict a collapse of ecosystems driven by technological overreach and the exploitation of natural resources, offering a powerful critique of modern society's environmental practices. In *The Windup Girl*, the consequences of genetic engineering and the commodification of life are explored, while *The Water Knife* focuses on water scarcity and its socio-political impacts. Through an ecocritical reading of these works, the article emphasizes the dangers of human estrangement from nature and the potential for ecological collapse. Bacigalupi's narratives not only reflect real-world environmental concerns, but also challenge readers to reconsider humanity's relationship with the natural world and advocate for sustainable practices to prevent future crises.*

Keywords: *Environmental degradation, dystopia, resource exploitation, genetic engineering, water scarcity, ecological collapse.*

Introduction

Ecocriticism, as a framework for understanding literature, explores the intricate relationship between human beings and the environment, focusing on the consequences of ecological exploitation and the growing disconnect between humanity and the natural world. Through this lens, it emphasizes the urgency of addressing environmental degradation, not only for the survival of ecosystems but for the continuity of human life itself. Paolo Bacigalupi, an American author known for his speculative and science fiction works, has written extensively on these themes. His novels, particularly *The Windup Girl* and *The Water Knife*, provide profound critiques of humanity's destructive relationship with the environment. Through his dystopian narratives, Bacigalupi imagines futures where the

exploitation of natural resources and the overreliance on technology have led to the collapse of ecosystems and societies. Eco critics ask questions like

What role does the physical setting play in the plot of this novel? Are the values expressed in this play consistent with ecological wisdom? How do metaphors of the land influence the way we treat it? How can we characterize nature writing as a genre? In addition to race, class, and gender, should place become a new critical category? Do men write about nature differently than women do? (Glotfelty xix)

In literature, nature is often a silent witness to human actions, but in Bacigalupi's works, nature becomes an active force that humans must reckon with. This treatment of nature aligns with the principles of ecocriticism, which challenge the anthropocentric view that human beings can control and dominate the environment without consequence. Bacigalupi's dystopian worlds reflect the consequences of such hubris, where human disregard for the environment leads to catastrophic outcomes, reshaping societies and creating new forms of suffering and oppression. His novels act as a warning of what could happen if humanity continues to exploit natural resources irresponsibly, ignore ecological balance, and neglect environmental stewardship.

Ecocriticism in *The Windup Girl*

The Windup Girl is set in a future Bangkok, a city teetering on the brink of collapse due to rising sea levels and the decimation of biodiversity. In this world, corporations control the last remaining genetic material of essential crops, and genetically modified organisms (GMOs) dominate the landscape. The central character, Emiko, is a genetically engineered being known as a "Windup." She is the product of human experimentation and commodification, created to serve as a labourer and treated as less than human. The novel examines the way humanity's manipulation of nature can lead to disastrous outcomes, not just for the environment but also for social and moral structures. Emiko's existence symbolizes the extent to which humans are willing to commodify life, a metaphor for the broader exploitation of nature in the service of profit. Anderson describes how the primary produces like fruit bearing plants and plants have simply gone. Anderson says that "There are no oranges, now. None of these...these...dragon fruits, none of these pomelos, none of these yellow things...lemons. None of them. So many of these things are simply gone" (TWG 93).

In *The Windup Girl*, Bacigalupi also draws attention to the fragility of ecosystems and the irreversible damage caused by humanity's overreach. The depletion of biodiversity, symbolized by the seed banks that characters in the novel fight to control, reflects real-world concerns about the extinction of species and the loss of genetic diversity in agriculture. The

novel imagines a future where the natural world is no longer self-sustaining but has become entirely dependent on human-engineered solutions. This vision of a world where nature is reduced to a commodity mirrors the concerns of ecocritics, who argue that modern technological and industrial advances have increasingly distanced humanity from the natural environment, resulting in ecological crises. Bacigalupi's portrayal of genetic modification as a double-edged sword—offering solutions to food scarcity while simultaneously creating new vulnerabilities—highlights the risks of tampering with nature without regard for long-term consequences.

Ecocriticism in *The Water Knife*

Similarly, in *The Water Knife*, Bacigalupi focuses on the theme of water scarcity in the American Southwest, a region ravaged by climate change and political instability. In this novel, water has become the most precious resource, and control over water rights determines who lives and who dies. The story's protagonist, Angel Velasquez, works as an enforcer for one of the corporations that control water distribution, using violent methods to secure water for the wealthy while leaving others to suffer. The novel depicts a world where environmental collapse has intensified inequality, as the wealthy build secure, self-sustaining enclaves while the poor struggle to survive in desiccated, dust-laden cities.

The Water Knife is a stark reminder of how environmental crises disproportionately affect marginalized communities. Those with wealth and power can shield themselves from the worst effects of climate change, while those who are already vulnerable bear the brunt of its impact. Bacigalupi's narrative critiques the way environmental degradation intersects with socio-economic inequality, showing how the fight for survival in a world without sufficient natural resources exacerbates existing divisions in society. The novel portrays a future where water scarcity has led to societal collapse, with states and cities warring over access to dwindling supplies, and the most basic human needs—water, food, and shelter—are commodified. In this dystopian vision, the environment is no longer a backdrop for human activity but the central battleground where life and death are decided.

In Hindu tradition, the river is associated with healing properties. Poets and authors hail a river as a mother, who bestows water to her children. In the Indian context, the river is associated with healing properties. River is seen as sacred in various religions since it is associated with Gods. Gita Mehta in *A River Sutra* brings to light the sacredness of the river Narmada. She says "A mere glimpse of Narmada's waters is supposed to cleanse a human being of generations of sinful births" (Mehta151). River Ganges is considered sacred by the people of India. River Ganges is associated with healing and is endowed with feminine

qualities. The people of Thailand are surrounded by sea water and they do not have water to drink. The scenario in the novel *The Windup Girl* reminds one of Coleridge's poems, *The Rime of the Ancient Mariner* in which the mariner laments about the excessive amount of sea water around him, but he doesn't have fresh water for drinking purposes. Likewise, the people in the novels are enclosed by water bodies, which consist of salt water. They are deprived of fresh water sources which are essential for human needs.

Bacigalupi's works draw on real-world environmental concerns, particularly climate change, resource depletion, and the consequences of unchecked technological progress. His depiction of a future shaped by ecological collapse is not far removed from the environmental crises we face today. In *The Water Knife*, for example, Bacigalupi explores how the failure to address water management and climate change can lead to the collapse of civil order. The novel's portrayal of water wars, where access to clean water becomes a privilege of the elite, is a chilling reflection of the growing concerns about water scarcity in many parts of the world today. Similarly, the genetically modified crops and organisms in *The Windup Girl* are a reflection of current debates about the role of biotechnology in agriculture and the long-term sustainability of GMOs.

Through his speculative fiction, Bacigalupi forces readers to confront the possible futures that wait if humanity continues to neglect environmental sustainability. His dystopian worlds are not just cautionary tales but urgent calls for action, reminding us of the interconnectedness between human survival and the health of the planet. By exploring the consequences of ecological degradation, Bacigalupi aligns his narratives with the goals of ecocriticism, which seeks to bring environmental issues to the forefront of literary analysis and public consciousness. His novels emphasize that humanity's future depends on its ability to live in harmony with nature, rather than in opposition to it.

In addition to their ecocritical themes, Bacigalupi's works are notable for the way they blend elements of science fiction with realistic concerns about environmental and social justice. While his novels imagine futures that are technologically advanced, they also critique the idea that technology alone can solve the environmental challenges facing the world. Instead, Bacigalupi suggests that without a fundamental shift in how humans interact with the environment, technological advancements will only exacerbate the problems of ecological collapse and social inequality. His speculative fiction, therefore, serves as both a critique of contemporary environmental practices and a vision of the possible consequences if those practices remain unchanged.

Conclusion

In conclusion, Paolo Bacigalupi's *The Windup Girl* and *The Water Knife* offer powerful critiques of humanity's relationship with the environment through the lens of ecocriticism. By imagining dystopian futures where ecological collapse has led to societal breakdown, Bacigalupi challenges readers to consider the long-term consequences of environmental neglect. His works highlight the dangers of commodifying nature and exploiting natural resources without regard for sustainability, while also exploring the social and ethical implications of these actions. Bacigalupi's fiction serves as a timely reminder that the choices humanity makes today regarding the environment will have profound consequences for future generations. Through his ecocritical perspective, Bacigalupi not only entertains but also educates and warns, urging society to rethink its relationship with the natural world before it is too late.

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Disclosing of Voices: Analysis of Maya Angelou’s “Still I Rise” and V.I.S. Jayapalan’s “The Song of the Defeated”

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ABSTRACT

The paper aims to explore the plight of the marginal people through the poems “Still I Rise” written by Maya Angelou and “The Song of the Defeated” written by V.I.S. Jayapalan. It brings out the struggles faced by the marginalized to gain a sense of identity. The identity crisis of the Sri Lankan Tamils and the African Americans is analysed through the poems. The sense of alienation, lack of opportunities, respect and equal treatment is brought out. It also implores the mindset of the people and their rebellious nature to stand up against the injustice, focusing on the defiant and furious tone used by the poets to project their strong sense of objection. It specifically scrutinizes the crucial role of the tone used in the poem, which acts as a contrast to many other marginal writings. It also highlights the difference in location, and ethnic groups based on which the poems are sketched. The themes of oppression, quest for change, rebellious nature brings a sense of unity between the poems which is clearly presented. The crucial and revolutionary role of literature in revolting against the oppression is also sketched. The paper particularly discusses the superior mindset and the cruel attitude of the people towards the other communities that is pushed to the periphery. It showcases that the themes of oppression and superiority are not just the problem of a single community but a global problem. The poems are analysed with reference to the timeframe in which they are written.

Keywords: *Race, Oppression, Hope, Struggle, Literature, Marginalised, Periphery*

Introduction

Literature is the mirror of contemporary society. It acts as a record of history with varied emotions and aesthetics. It is used to express the inner emotions and desires of a human. The word ‘marginalized’ is derived from the Latin word ‘margo’ which means border. The term was used to refer to the people who lack power or influence in the society. They are often treated as outsiders in the society in which they live. The marginalized people have used literature as a powerful weapon to express their indescribable sensation. They transform their writing into a revolution by transferring their thoughts into the minds of the readers. The marginal writers do not just write their personal struggles but bring out the

problems faced by the entire community they represent, which acts as a microcosm of the entire society. De Bonald has said that, “Literature is an expression of the society”

The paper brings out the complex emotions and feelings of the marginalized people through the poems, “The Song of the Defeated” by V.I.S. Jayapalan and “Still I Rise” by Maya Angelou.

The Song of the Defeated

The poem “The Song of the Defeated” is written by V.I.S. Jayapalan, a Sri Lankan-Norwegian writer. He vividly describes the pains and torments undergone by the Tamils who were treated as marginal people in Sri Lanka. Though they have made their settlements years back they were not accepted as a part of the nation. The inhumane treatment, injustice made to them is picturized by the author through his words. The Tamil people in Sri Lanka were treated as marginalized people because they were considered a minority. The Sri Lankan civil war was the outburst of the tensions that prevailed between the Sri Lankan government and the Sri Lankan Tamils, in which a lot of Tamil people were brutally killed and humiliated.

Still I Rise

The poem “Still I Rise” is written by Maya Angelou. She is an African American writer and she has brought in the condition of the Africans settled in America. In spite of America being a settler colony, the blacks were considered as subordinate based on their skin color. Angelou intrusively writes about the atrocities faced by them with a note of hope and pride. It clearly represents the pains of the Black women and their courage to withstand. It had a strong association towards the civil rights movement and the Black feminist movement.

Both the poems have the themes of oppression, identity crisis and a sense of hope and revival. Though both poets has written about two entirely different parts of the world, the treatment they have received is almost the same. From this we could understand the mindset of the oppressors and their sense of superiority towards the other, oppressed humans. Eventually it disturbs the normal life of the people and makes them marginalized.

The poems have been written almost in the same time period, which is around 1970’s which again authenticates that these themes could not be confined to a particular place, ethnic group or community. The tone used by both the poets is again notable. It highlights the spirit of the marginalized people. They have used a bold tone and they do not mourn for their past.

“Leaving behind nights of terror and fear

I rise

Into a daybreak that’s wondrously clear

I rise

Bringing the gift that my ancestors gave,
I am the dream and the hope of the slave.”

They did not try to conceal their failures and slavery, instead they took it as a worthy reason to change their living conditions. Maya Angelou in her poem has used the phrase “Still I Rise” as a refrain, which emphasizes her spirit to attain victory amidst the harsh realities. She uses a mocking style to show her fearlessness. Likewise, Jayapalan has come up with a paradoxical title, “The Song of the Defeated” which questions the conventional concepts. Songs are usually a part of victory but Jayapalan says that though the Sri Lankan Tamils have been defeated in physical means, their inner spirit still burns with rage and that rage is worthy of praise or a song. Both the poets do not express shame for their situation but has understood the means to overcome it through their powerful writings. Moreover they are not willing to fake their identity, which has made them failures. Instead they are proud of their identity. It is evident from Angelou’s lines from the poem,

“I’m the black ocean, leaping and wide,
Welling and swelling I bear in the tide.
Leaving behind nights of terror and tear
I Rise”

In both the poems the poets have mentioned about their ancestors which again shows their sense of pride. They honour the efforts of their ancestors, who have become martyrs for their race and they also thank them for the unique knowledge that they have passed to the younger generation. They glorify their tradition by bringing in their cultural beliefs and practices which shows their strict adherence to their native culture and tradition. It also reveals their mindset that they are glad about their ancestry amidst the undesirable treatment they have received. Jayapalan has brought in the concept of kula dheivangal who are not just Gods but fierce warriors who have fought to save their people.

“They will discover Karuppusamy, Kathavaranyas,
Madurai veerans like Deepan
Who became a shooting star at Mullivaikal.”

Similarly Angelou has revealed the signs of their traditional wealth. She describes that they were wealthy through the words diamonds, goldmines and oil wells. This shows their sense of pride and attachment to their identity though they were not accepted as a part of the place where they live.

The poets have come to a point that they can be treated in such cruel ways because of the unquestioned authority of their oppressors. But they would do it as a form of

encouragement. According to Jayapalan, their inefficiency to attack their rivals back is also a form of an antidote for their pains and struggles. The poets do not expect an equal treatment from the people who ill-treat them. Jayapalan does not plead them to treat them as equals instead he narrates the atrocities done to them, and instills hope through his words that they would gain their rights.

“We are a charred forest
 But our song continues
 From the roots that remain
 Our song will continue
 As a dirge for the dead”

Both the poets have come up with an impression that their rivals are afraid. They have not just recorded the mindset of the marginalized people but also have tried to come up with the mindset of the people who suppress them. According to Jayapalan, they celebrate the defeat of the Sri Lankan Tamils but still they grow weak because within their hearts they know that what they have done is a pure act of injustice.

They do not want the world to just sympathize for them but they attempt to show their caliber. They try to unveil their potential to gain a sense of identity amidst the identity crisis they face. Jayapalan records that they would turn self-criticism as a remedy to make a better attempt and to understand the reason for their failure.

In both the poems, the poets have associated them or their life to the natural elements which reflects their proximity with the traditional life. They find solace through nature. Jayapalan symbolizes them as charred forests whereas Angelou symbolizes them as moons and stars because they are never ending. Though they are not visible in the daytime it does not mean that they are gone forever and it states they would not succumb even if they are exposed to adverse situations. Though they are suppressed and ill-treated they revive as the sprouting shoots in a burnt forest. They both associate their spirit of hope to nature and its infinite existence just like that of nature.

The Song of the Defeated

The main purpose of the song is not to evoke a sense of pity among the readers. The poets have used their powerful verse with a strong diction as a form of revenge which portrays their undefeatable spirit to attain equality and gain a sense of identity. As they could not attack them directly, Literature helps them to create a way to express their internal emotions. In “The Song of the Defeated” Jayapalan comes out with the lines,

“If I cannot curse the legs that kick you,

What is the use of this song?”

Though Jayapalan has brought out the tortures they have undergone, he completely does not want to be a sympathetic figure. He makes a point that the failures they face instigate the burning zeal inside them. The same could be seen through the writing of Angelou, though she expresses their struggles, she did want the readers to perceive them as weak people.

More importantly both the Tamil community in Sri Lanka and the African American community in America have settled many centuries ago but they are not accepted as a part of the country which again questions the mindset of the people. The contributions of these marginalized people have been a major thing in the advancement of these nations but they have been almost concealed and have not been recognized.

Life of Marginalized

Marginalized people lead tough lives and struggle hard for their existence but the lives of women from such oppressed communities are even tougher. Women are the first hand victim of any violent environment. Being a marginalized person in a particular place is torturous but specifically being a woman adds a layer of pain to it. This has been enclosed by both the poets. They have vividly brought out the mental and physical trauma that a woman faces in such a situation. V.I.S. Jayapalan has started his poem in a hopeful tone but suddenly uses digression when he writes about women and their struggles. He says that he is filled with fear because they rape the Sri Lankan Tamil women brutally and proceed to live without any guilt. The emotions of those women are purposefully tested. They would be forced to see the men of their family being shot.

“This is the time of gods of a news lineage.

The anger of our raped women
will be reborn as fiery goddesses”

Similarly, Angelou also comes up with the problems faced by African American women. They were also brutally assaulted by their White masters, who are not blamed as they bear a place in the society as an unquestioned authority. Though the people of the marginalized community are treated as inferior, those women are still used as sexual objects by the men. From this we could understand that the writings of both V.I.S. Jayapalan and Maya Angelou are separated by the boundaries, ethnicity and race. Still they hold the same emotions and they also experience the identity crisis. They lack a sense of belonging in their own places where they were born and raised.

Conclusion

This study could be viewed through the lens of Archetypal theory. There is a vast difference in the cultural background of the people but the ideology of race, superiority, oppression and marginalization are found as common themes. This could be seen through the writings of Angelou and Jayapalan. Besides their differences in the themes there is a remarkable association in their writings. This could be associated with the concept of collective unconsciousness through which a particular majority group gains a form of superiority over the minority group in the name of class, community and race.

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Ancestral Echoes: A Critical Study of Family Dynamics in Nadia Hashimi's *The Pearl That Broke Its Shell*

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ABSTRACT

*The paper entitled "Ancestral Echoes: A Critical Study of Family Dynamics in Nadia Hashimi's *The Pearl That Broke Its Shell* explores how ancestry plays a vital role in shaping a family both physically and psychologically. Familial relationships are very predominant in affecting an individual's life to a higher level. One can achieve greater heights with the help of a supportive family as well as lose their lives when their emotions are subjugated. If the family is reassuring and considerate then there is progression in an individual's life. Societal norms often mirror the individual habits cultivated within homes. Thinking capacity, emotional connections, and inherent humanity are deeply influenced by the family dynamics within which individuals are raised. Individuals from prominent families can leverage their connections to achieve success. As a result the whole system of subjugation, inequality and dominance can be eradicated. Through the intergenerational stories of both Rahima and her great grandmother Shekiba, this paper analyses how familial relationships shape an individual's identity and destiny across generations. The paper also examines the role of mothers, sisters, and female solidarity in traversing tyrannical family structures and societal expectations. It also offers a nuanced portrayal of family dynamics in Afghanistan, revealing both the restrictive nature of traditional familial roles and the potential for resilience and change within these ancestral resonances. This paper endeavours to justify how family is essential in shaping an individual's life that too in a patriarchal Afghan nation.*

Keywords: *afghan, family, patriarchy, resilience, trauma*

Introduction

Nadia Hashimi is a pediatrician, novelist and also a former democratic congressional candidate for the United States House of Representatives. She was born on December 12, 1977, in Queens, New York to Afghan parents. Her parents immigrated to the United States in the early 70's. She is an Afghan-American novelist. She is best known for her debut novel *The Pearl That Broke Its Shell*, a story connecting the lives of two women even after centuries apart. This novel published in 2014 was an international best seller and was translated into multiple languages. Hashimi always intended her novel to be empowering for

women. In an interview with Girls' Globe- the global feminist media platform for gender equality, human rights, social justice and sustainability, Hashimi says, I see Rahima and Shekiba as every woman. When I read Rumi's lines, the sea is Rahima's inner voice, expansive and powerful, beckoning her to break free and realize her potential. We all need to mind that voice that lives within, that tells us to want better for ourselves to not throw up our hands in defeat. (Girls' Globe)

Sisters' Rapport

The novel opens with the story of Rahima, a nine years old girl who lives with two elder sisters, Shala and Parwin and two younger sisters, Rohila and Sitara. Shala, the first born is average looking and takes extra effort in beautifying herself. She speaks maturely and is well spoken to people around her. Hashimi describes "People looked at her and couldn't help but smile. Polite and proper, she was a favourite in school. She had a way of looking at you and making you feel important" (6). On the other hand, Parwin is just the exact opposite of Shala. She lacks social skills but is good at artistic skills. "She had a gift, an ability to show you what you did not see, even though your eyes graced the same sights as hers. She could sketch a masterpiece in minutes but washing the dishes could take hours" (7). Unfortunately, she is born with a bad hip and a limp. Meanwhile, Khala Shaima is also born with a crooked spine. She is the eldest aunt of Rahima and she is a savior to the family. Due to her physical deformity, her parents couldn't find her a suitor.

People made fun of her disability for having a hunched back and one raised shoulder. This is the reason why Khala Shaima did not make any efforts to beautify her or even dream about her marriage. She is seen taking high responsibilities of everything around her. She looked after her old parents, supervised every single thing around her. She is one among the strongest women characters in this novel who is very optimistic about life and also stood for her own rights as well as voiced for the rights of her loved ones. Rahima comments, "She was a safety net for anything our parents might not have been able to do for us and she was one of the few people who could stand being around *Padar-jan*" (9). She is so strong willed to let her nephews and nieces get a better education. Shaima couldn't digest the fact that the girls will no longer be sent to school. She comments, "If you hold these girls back for that, you're no better than the Taliban who closed their schools" (11). These women truly represent the traditional as well as modern Afghan familial situations in an understandable way.

This story traces back the lives of two women, Rahima and her great-great grandmother Shekiba, who becomes a prey undergoing humiliations and sufferings due to

their family situations. Shekiba's story inspired Rahima to become a bacha posh. As a boy, Rahima got the opportunities that were usually denied to girls in Afghan rural society then, foremost of which was the opportunity to be educated. Both of them struggle to overcome oppression and male domination that is all too commonly faced by women in patriarchal society. The two protagonists of the novel, Rahima and Shekiba live in Afghanistan some hundred years apart. Shekiba is Rahima's great-great-grandmother, yet they are bound by similar fates and destiny that entangle them as they live a century apart. Both women had adopted the custom of bacha posh, which gave them a respite from the oppressiveness of the Afghan society.

Father – a Major Figure

In Afghan families, the father is the major figure and plays a huge role in taking any decisions in their daughter's life whereas the mother is seen voiceless under her husband. This story uncovers how decisions undertaken by parents or husbands without the consideration of their children, especially daughters, collapse their future and their lives as a whole. It also reveals their longingness to get back their single life. A father's role is an essential part in the development of a healthier family. A father must be able to see the futuristic view of their children before stepping into any decision. Asif, Rahima's father works under a warlord. Being an opium addict he always behaves rough at home. "It made him do funny things, behave in funny ways. Mostly he wanted to lie about the house and sleep. Sometimes he said things that didn't make sense. And he never remembered anything we said. It was worse when he didn't take his medicine" (24).

In the initial stage, Asif is unable to tolerate the fact that his girls are being chased by the local boys in the streets. He denies allowing his daughters to school thinking about the problems caused by the boys in the streets on their way back home. He fails to think about the future of all his daughters. As a result of his stubborn decision he denies their education and makes them stay at home helping their mother with household works.

Later he forces his daughters to marry at a young age to men who are five times his daughter's age. He is a typical example of an Afghan father with a patriarchal mindset. A mother is equally important to a child like that of their father. But in Afghanistan, a wife or a mother is considered to have the most pathetic situation in a family life. She doesn't even have rights to give suggestions in important family matters. A wife is considered as a voiceless person, a woman who is suppressed by her husband. Rahima's mother is seen as a mouthpiece of contemporary women in Afghanistan, who wholeheartedly dislikes all of their husband's decisions but was left in a terrible state to sob for their daughters' lives.

Rahima is married to her father's warlord, Abdul Khaliq and Shala and Parwin are married to Abdul Khaliq's cousins. The internal traumas of these three young girls coping up to forcefully marry older men cause psychological traumas inside them. After all, they are not even adults to think of marrying at a young age. They aren't psychologically prepared to step out of their house to get into a new phase of life. They are still young girls who are in need of a mother's love as a strong pillar of support to mould them. Without any other choices left, they enter into marriage and get shifted to their husbands place. They long to be with each other the very next second they moved out of their house. Their longingness to visit their parents, know about their health, about their siblings and their surroundings are like a dream to them. Nothing smoothens their ways to fulfill their desires.

Marital Life

A good marriage is based on mutual understanding and the trust the partners have on each other. Rahima did not have a happy married life, nor did Parwin and Shala. She did all the household chores and everything the family wanted her to do. She was literally treated like a servant in her husband's place. Her husband physically abused her and she felt absolutely powerless and voiceless under him. Rahima says, "I hated that I was powerless under him. I was supposed to be this man's wife and that changed everything. I wasn't supposed to fight back. And the look on his face told me that fighting back would only make matters worse" (174).

A child brings so much happiness into a family. In Afghan society, a male child is considered as a source of pride. The inability of Rahima's mother in bearing a male child sucks her father's mind. Whereas in Rahima's case, she is blessed with a baby boy. She is relieved as bearing a boy adds value to married women. Rahima's internal traumas change to some extent when her focus shifts on her child. She describes, "Jahangir was my salvation-his face became my escape. He gave me reason to rise in the morning and to hope for tomorrow" (212). On the other hand, Parwin suffers a lot with her physical deformity. She undergoes mental traumas and is left helpless without even having a person to share her emotions. Parwin ends her life not being able to cope with the people around her. The whole family is shattered by the death of Parwin. Finally this death has only made the family unite once again after they left their home. The pathetic plight of the family takes its shape with that of the selfish decision of their father to marry them in return for excessive opium. As an opium addict he considered opium to be far superior to that of his daughter's lives.

Rahima and Shekiba might have adopted similar techniques to deal with their lives, but they were oppressed in different ways. Ultimately though, the two women also had

different approaches to life. Rahima was definitely the stronger of two, as she refuses to accept oppression even in the face of danger. On the other hand, Shekiba allows herself to be the part of the system for survival. Though it could be the fact that Rahima lived a hundred years after Shekiba, or that she had Khala Shaima fighting in her corner, while Shekiba had no one. However, the fact remains that even a hundred years later, women are oppressed.

Towards the end, Rahima gets the courage she needed and longs for a transition in her life. She remembers the lifestyle of women in Kabul's parliament. This gave her a choice to change her life. She longs for freedom like the women in Kabul. Rahima comments, "They were independent and happy, something I'd tasted only as a young boy" (308). Rahima wishes to get back her past life as a young girl disguised as a bacha-posh wandering carefree in the streets. She finally thinks of an escape from the oppressed life she has been witnessing all these years. "An escape. I need to find an escape" (411).

Conclusion

As mentioned in the article by Jibin Monish V & Dr M. Kannadhasan titled, "The Struggle of Women against Oppression – A Study of Nadia Hashimi's *The Pearl That Broke Its Shell*: The bravery of Rahima inspires others to resist persecution. She finds a safer haven by fleeing to a shelter. She is free to live her own life without being oppressed. She is saved from male dominance since she can do it independently of her husband. In the end, she will be able to free herself from men's dominance. When she is at the shelter, she discovers that anyone can save her life from oppression by getting an education. She understands that education can be a weapon in her fight against the patriarchal society that oppresses her. (1214).

Afghanistan is seen as a nation with various familial norms and stereotypical family dynamics. The female characters presented by Nadia Hashimi are victimized by their own circumstances, thus undergoing transition in life and remain suppressive in a patriarchal society. It's in the hands of men to consider women as a part of the family rather than treating them like domestics. Daughters must be provided proper education like that of a son in Afghan society. The stereotypical mindset of Afghan people must be reformed in order to bring out an enhanced society. Thus the paper instills in us a proper view of the familial lives of Afghan people and how women are powerless and victimized within their own families.

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**Colonial Narratives Reimagined:
Fact and Fiction in Amitav Ghosh's *Flood of Fire***

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ABSTRACT

Amitav Ghosh's Flood of Fire, the concluding novel in his Ibis Trilogy, serves as a meticulously crafted historical narrative that intersects fact with fiction. This paper examines how Ghosh, a novelist and anthropologist renowned for his thorough research and literary sophistication, uses the trilogy to explore the British opium trade with China during the 19th century, along with the colonial subjugation and migration it precipitated. By focusing on underrepresented voices, subalterns and marginalized figures, Flood of Fire highlights cultural and political dimensions of colonial oppression. The narrative spans multiple characters across diverse cultural and geopolitical landscapes, reflecting the complexities of identity, belonging, and resistance within colonial frameworks. Employing postmodern techniques such as genre-blending, meta-narratives, and magic realism, Ghosh's work recontextualizes imperial history, engaging readers in a discourse on nationalism, cultural hybridism, and the impact of colonial legacy. This paper investigates how Ghosh's blending of history and fiction offers a nuanced understanding of the socio-political and cultural implications of British imperialism in Asia, creating a compelling narrative that appeals to both historical and postcolonial scholarly perspectives.

Keywords: Colonialism, Hybridism, Identity, Imperialism, Migration, Resistance,

Introduction

Amitav Ghosh's works stand out for the depth of research he invests in each novel and for his extensive travels through the places he writes about. Describing himself as a traveler interested in "men, places and scenery," Ghosh believes that traveling expands awareness into realization (qtd. in Bijay 56). His journeys through the Middle East, South Asia, North Africa, Europe, America, and Egypt influence his writing, imbuing each book with a unique and elegant simplicity. Raised with discipline by his father, Lt. Col. Shailendra Chandra, Ghosh witnessed the 1984 riots in India, which shaped his exploration of the relationships between nation and individual, as well as cultural societies and the individual, within his novels. As Bijay notes, "Ghosh's achievement, like that of any gifted historical novelist, lies

in his ability to extract from actual events a set of characters whose fictional identity is camouflaged by their plausible interaction with their environment and by their ability to appeal to readers” (56).

In his works, Ghosh explores history not as a historian, but as a literary figure. His extensive travels across the world and doctoral research at Oxford are evident in his writing. As a novelist, he delves into human societies and their interconnectedness. Ghosh’s narratives present unconventional methods of portraying history, culture, politics, nations, and anthropological aspects of humanity. His works are imbued with Indo-nostalgic elements, combined with his philosophical perspectives and strong postcolonial themes. Besides history, Ghosh’s novels encompass other subjects. For instance, *The Circle of Reason* includes topics such as ornithology, phrenology, handloom weaving technology, and the etymology of cotton, alongside historical episodes in the sciences. *The Calcutta Chromosome* addresses microbiology, genetics, linguistics, and computer science, while *The Glass Palace* reflects knowledge of teak logging, rubber cultivation, photography, and military regimental traditions. In his *Ibis Trilogy*, Ghosh vividly depicts the opium trade, jail life, the struggles of Indian sepoys under colonial rule, maritime life, the shipping industry, and the internal workings of an opium factory.

Historical Fiction

The *Ibis* trilogy, a work of historical fiction by Amitav Ghosh, comprises *Sea of Poppies*, *River of Smoke*, and *Flood of Fire*. Set in the first half of the nineteenth century, it explores the opium trade between India and China orchestrated by the British East India Company, as well as the trafficking of indentured labourers (or “coolies”) to Mauritius. During the nineteenth century, opium became central to the British economy in India, financing much of the British Empire's operations there. Beginning in the 1780s, the East India Company greatly expanded poppy cultivation and opium production in India, draining significant wealth from the country. Under British supervision, large-scale opium production commenced in Eastern Uttar Pradesh and Bihar, where farmers were pressured to devote their lands to poppy cultivation. Much of this raw opium was then exported to China in a deliberate effort to create dependency among Chinese citizens. In regions around the Gangetic plains, peasants were compelled to abandon traditional crops in favor of poppies.

Nancy Oakes, in her review on Goodreads, describes the *Ibis* trilogy as “an amazing critique of colonialism/imperialism” that illuminates how the financial gains from the opium trade transformed “individuals, families, communities, nations, diplomacy, and international relations” (Oakes). Similarly, Zac O’Yeah, in a review for *The Hindu*, comments on Ghosh’s

linguistic prowess, noting the “utter delight” Ghosh takes in incorporating Hobson-Jobson-style Indian-English expressions that evoke the nineteenth century but have since fallen out of use (O’Yeah 4).

Fact and Fiction

In *Flood of Fire*, Ghosh recounts the events leading to the First Opium War, using fiction to offer a critical perspective on the oppression experienced by Indians and Chinese under British imperial rule. By centering the voices and experiences of marginalized characters, Ghosh highlights the lives and struggles of individuals overlooked in traditional histories. His writing provides a platform for subaltern voices to confront oppressive societal forces, presenting an expansive and imaginative narrative of colonization in India and China. Through a colonial lens, Ghosh examines the devastating effects of imperialism on migration and the suffering of the colonized.

Ghosh is highly critical of Britain’s policies in Asia during the colonial era, shedding light on a largely forgotten period of history. His trilogy emphasizes the realities of slavery and the opium trade, recounted from the perspective of imperial-era historians. Ghosh, like a historian, reimagines history through fiction to present an alternative yet faithful retelling. Blending fact with fiction, Ghosh recreates historical society with meticulous research and creative narrative techniques. The sacrifices and hardships that history has often neglected find a prominent place in his work. His novels document the smuggling of opium and the broader implications of colonial oppression, depicting its historical impact with realism and detail.

Amitav Ghosh’s tendency to blend genres produces unparalleled works of literature, a literary innovation in which Ghosh is a supreme master. Blurring genres—a hallmark of postmodernism—is evident in Ghosh’s writings. *Flood of Fire* is not merely a novel; it is a romance, a narrative fiction, and a historical fiction. The novel brims with rich historical details, clearly the result of prodigious research. However, at times Ghosh includes background information that, while helpful for readers unfamiliar with the earlier books in the trilogy, can weigh down the narrative. Neel’s section of the novel, written in the form of a diary, occasionally lacks the drama and immediacy found in other parts. Yet Ghosh’s passion for his subject, his care for his characters, and his command of prose allow readers to become fully immersed in the story.

Ghosh effectively employs postcolonial narrative devices such as magic realism, metafiction, mixed genres, subversion, deconstruction, and “story within a story” to interrogate, reject, and resist Western hegemony, and to reconstruct and reaffirm the non-Western perspective.

This distinguishes Ghosh as a prominent postcolonial novelist in the contemporary context. In *Flood of Fire*, Ghosh spends the first two hundred pages developing the backgrounds of four central characters: Shireen, a Parsi widow of an opium merchant; Kesri, a brave and loyal colonial soldier of low birth whose sister disappeared after a troubled marriage; Neel, a fallen Indian nobleman now chronicling political developments from China; and Zachary, a young American eager for success despite past misadventures and criminal charges from his first voyage on the *Ibis*. Ghosh eventually gathers these characters aboard the *Hind* and sends them to China, delivering a denouement that intertwines personal and historical moments and offers insightful reflections on the *Ibis*. The structure of the novel resembles a jigsaw puzzle with seemingly disordered pieces that are gradually revealed to be part of an intricate design. This form conveys to both the narrator and reader that the world cannot be fully understood through simple maps or atlases. According to *The Scotsman*, “In the last chapters, Amitav Ghosh pulls the strings of his enthralling trilogy together” (Allan).

In *Flood of Fire*, Ghosh narrates events leading up to the First Opium War. He uses fiction as a vehicle for historical storytelling. The novel is set in 1839, a time of rapidly escalating tension between China and British India as the crackdown on opium smuggling intensifies. With no resolution in sight, the colonial government declares war. The British are determined to open China to the opium trade, while Commissioner Lin, a Chinese official, fights to keep the drug out. Initially, Lin believes the opium traders lack the British government’s support, but he soon learns otherwise.

The novel begins with a vivid description of the British military’s march to war, introducing readers to a host of characters as the drama unfolds. Handsome Zachary Reid, burdened by debt, accepts a job restoring a houseboat in Calcutta, only to become involved in an affair with Mrs. Burnham. Meanwhile, in Bombay, Parsi widow Shireen Modi is devastated by news of her husband’s mysterious death after falling from his ship, *Anahita*, in Hong Kong. Determined to recover her husband’s investments, Shireen travels to China despite the looming war. Simultaneously, Neel Rattan Halder, a dispossessed Bengali zamindar, sails to China as secretary, or *munshi*, to a Parsi businessman. Settling in Canton, Neel becomes embroiled in events as Britain and China prepare for war, ultimately serving as an interpreter for Chinese officials like Zhong Lou-si and Compton, representing India’s role in the conflict.

In *Flood of Fire*, Amitav Ghosh presents a unique historical perspective through fiction, examining the processes of colonization in India and China with imaginative depth. Through his characters, Ghosh addresses complex issues such as identity, subalternity, and

belonging. Notably, he highlights the irony of Indian soldiers, like Kesri Singh, who, while fighting in British-led wars, neither defended nor expanded Indian territories but instead served to further British colonial expansion. This irony underscores the complexity of colonial identities, where individuals from colonized societies were made complicit in the exploitation of both people and land.

Ghosh meticulously recreates the cultures of nineteenth-century India and China, providing a rich tapestry of characters from diverse cultural and geographical backgrounds. Through this diversity, he illustrates the significant role culture plays in shaping individual lives and identities. The novel reveals how colonizers subjugated the colonized, particularly through cultural and economic means disguised as globalization and free trade. As Ghosh traces the lives of various characters, he explores their efforts to reconstruct identities, adapting to the cultural and colonial challenges they face.

Elizabeth Lucy in her article in *Crossian Resonance* says that Ghosh in his novels in the *Ibis* Trilogy:

deals with Cultural subordination of the people beyond geographical and political boundaries in trade and commerce and questions the past, tradition, culture, and identity. Characters of mixed parentage: Ah Fatt, the illegitimate son of Bahram, the Cantonese boat woman, French orphan Paulette, the greedy opium traders like Seth Bahram . . . and the marginalized characters of China affected by opium trade undergo identity crisis. (4)

Many immigrants find a need to change their cultures in order to fit into the culture of most citizens in the country. This can cause conflict with a person's current belief in their culture and might pose a problem, as they feel compelled to choose between the two presenting cultures. While some might be able to assimilate to the various cultures in the world by committing to two or more cultures, namely the native culture and the culture of the colonized, some cannot. Their cultural identity is threatened and they experience fluid identity. Characters like Neel, Ah Fatt and Zachary Reid use different names in different places and situations to conceal their identity. Thus, cultural identity is able to take many forms and can change depending on the cultural area. This elastic nature of culture allows people to feel like part of society wherever they go. Brinda Bose comments:

Ghosh's extraordinary oeuvre of fiction and nonfictional essays hangs somewhere between the warm security of location and terrifying – if exhilarating- promise of imminent dislocation, sometimes with a foot in each but most often balanced precariously at the moment of dis / junction. This moment is predicated upon not just

the significance of the loss of locatedness but also upon one's consciousness of the process of losing that precious 'lived sense of place', a 'distancing' that Ghosh identifies as the catalyst for the possible birth of the novel (13).

Amitav Ghosh's novels explore various issues of the postmodern era, including themes of fluid identity, migration, plurality, hybridism, multiculturalism, and the blending of fact and fiction. Common motifs in his work human insecurities and a questioning nature underscore Ghosh's narrative strategy as he addresses the challenges of modern life. Trained as a historian and anthropologist, Ghosh connects past and present by reinterpreting historical events with a creative lens, weaving magically realistic plots that reflect human predicaments, disasters, dislocation, and displacement. Elizabeth Lucy, in her article in *Crossian Resonance*, observes, "the national identity of the third world nations is projected as that of Otherness with its different systems of knowledge and socio-political realities" (Lucy 3). Ghosh's style is characteristically postmodern, as seen in *Flood of Fire*, where the narrative flows back and forth between different times, places, and characters, providing clarity through simple language. His technical prowess is remarkable, using postmodern devices to add depth and intensity to his novels.

Conclusion

The *Ibis* trilogy has enjoyed success among readers and critics alike, with the first two volumes winning multiple awards and securing Ghosh's place on the shortlist for the Man Booker International Prize. This popularity may stem from the trilogy's depiction of British imperialism and its underlying sense of optimism, a reflection of Ghosh's perspective rather than that of his historical subjects. Through his Indian characters, who act as agents of their own destinies, Ghosh conveys a sense of empowerment, with many ultimately escaping the clutches of colonialism. Notably, Ghosh's approach to English reflects his postcolonial perspective, treating the language as "just one among many" that he speaks.

As an anthropologist with extensive travel experience, Ghosh comments on contemporary global issues in his novels, addressing cultural fragmentation, colonial and neo-colonial power structures, cultural degradation, materialism, the erosion of human relationships, and the search for love and security. Themes such as the blending of fact and fiction, diasporic identities, and a disdain for restrictive national boundaries are central to Ghosh's narratives, which often focus on multiracial and multi-ethnic issues. As a cosmopolitan figure, Ghosh weaves these themes with narrative grace, emphasizing the universal human experience.

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அன்பின் மொழியே மழலைமொழி

*¹ஜெயகலா வி., ²ஆன்றின் மேரி எஸ். & ³ஸ்னோ ஜெ. ஷர்மிளா

¹நூலகர், ஹோலிகிறாஸ் கல்லூரி (தன்னாட்சி), நாகர்கோவில் - 629 004

²கணிதத்துறை, ஹோலிகிறாஸ் கல்லூரி (தன்னாட்சி), நாகர்கோவில் - 629 004

³ஆங்கிலத்துறை, ஹோலிகிறாஸ் கல்லூரி (தன்னாட்சி), நாகர்கோவில் - 629 004

மனோன்மணியம் சுந்தரனார் பல்கலைக்கழகம், திருநெல்வேலி - 627 012

கட்டுரைச் சுருக்கம்

அன்பின் மொழி என்பது மழலை மொழியே. அந்த மழலை மொழியின் ஆழம் அகலம் எதையும் நம்மால் கண்டுரை முடியாது. அதை அனுபவித்து உள்ளூரை வேண்டும். அந்த மழலைமொழியை இன்ப மொழியாக்குவதும், மகிழ் மொழியாக்குவதும் வளர்ப்பவரின் கையிலேயே தான் உள்ளது. இந்த மழலைப் பருவமானது சுயநலப் பருவம், உடலின்ப பருவம், தன்னம்பிக்கையில் வளரும் பருவம், குறும்பு பருவம் என்று பலவாறு அழைக்கப்படுகிறது. இப்பருவத்தை நாம் எவ்வாறு கையாள்வது நல்லது என்பது குறித்து இக்கட்டுரையில் காண்போம்.

முன்னுரை

‘குழல் இனிது யாழ் இனிது என்பர் தம் மக்கள் மழலைச்சொல் கேளா தவர்’ தம் மக்களின் மழலைச் சொல் கேட்டு இன்புறாதவர்களே, குழலிசை இனியது என்றும், யாழிசை இனியது என்றும் புகழ்ந்து கூறுவார்கள். அத்தகைய இனிமை வாய்ந்த மழலைப் பருவத்தில் அவர்களுக்குள் ஏற்படும் மாற்றங்கள் பலவிதம். அம் மழலைப் பருவத்தை சரியான விதத்தில் கையாண்டு வளர்த்தெடுத்தால் அவர்கள் வாழ்வு இனிமையாகும். குயவனிடம் கொடுக்கப்பட்ட களிமண்ணை குயவன் தான் விரும்பிய பாத்திரமாக வளைவது போல நம் மத்தியில் வளர்ப்பதற்கு இறை கொடுத்த மழலையைச் சரியானப் பாதையில் வளர்த்தெடுப்பது நமது கடமை.

மனதில் எளிதில் பதியும் பருவம்

“எந்த குழந்தையும் நல்லகுழந்தை தான் மண்ணில் பிறக்கையிலே அவர் நல்லவர் ஆவதும் தீயவர் ஆவதும் அன்னை வளர்பினிலே.” என்ற பாடல் வரிக்கேற்ப எல்லா குழந்தைகளும் பிறக்கையில் நல்லவராகவே பிறக்கின்றனர். ஆனால் நல்லவராகப் பிறக்கின்ற குழந்தையை நல்ல குழந்தையாக வளர்த்தெடுப்பது நம்மவர் கையில் தான் உள்ளது.

மழலைப் பருவம் எளிதில் பதியும் பருவம். இப்பருவத்தில் நாம் குழந்தைக்கு எதைக் கற்றுக் கொடுக்கிறோமோ அல்லது குழந்தை எதைக் கற்றுக் கொள்கிறதோ அதுவே அவர்கள் வாழ்வில் தாக்கத்தை ஏற்படுத்தும். நேர்மறை எண்ணத்தோடு வளர்க்கப்படும் மழலை தன் வாழ்வின் இறுதி வரை நேர்மறை எண்ணத்தோடு வாழ்ந்து சாதனைபுரியும். ஆனால் எதிர்மறை சூழ்நிலையில் வளர்ந்தப்படும் குழந்தை வாழ்நாள் முழுவதும்

பாதிப்புக்குள்ளாகும். இந்தநிலை மாற மழலைப் பருவத்தில் நேர்மறை சூழ்நிலையை உருவாக்க வேண்டியது நமது கடமையாகும்.

குழந்தையின் குணம்

“குழந்தையும் தெய்வமும் குணத்தால் ஒன்று

குற்றங்களை மறந்துவிடும் மனத்தால் ஒன்று.”

இறைவன் நாம் எத்தனை தவறு செய்தாலும் மன்னித்து மறந்துவிடுவார். அதேபோன்று தான் மழலைகள் மற்றவர் செய்த குற்றங்களை உடனே மறந்துவிடும் குணம் கொண்டவர்கள். மறந்து விடுவது மட்டும் அல்ல. அது அவர்களின் நினைவலைகளில் இருப்பதே இல்லை. சிறுசிறு குறும்புகளை விறுவிறுவென செய்யும் மழலை தன்னை வெறுப்பவர்களைகூட மனமாற நேசிக்கும். இதுவே மழலையின் குணம். அதுதானே இறை குணம்.

மழலையின் சிரிப்பு

‘உறக்கத்தில் சிரித்தால் கூட கண் இமைக்காமல்

பார்க்கும் கொள்ளை அழகு, மழலையின் அழகு - அப் புன்னகையில்

முற்றும் அடங்கி போகிறது அகவலியும், புறவலியும், கோபச் சுவடும்’

ஆம், மழலை சிரிப்பு மனதின் துன்பம் மறக்கும் மருந்து மட்டுமல்ல பிரிந்த உறவுகளை இணைக்கும் பாலம். அன்பை வெளிப்படுத்தும் அருமருந்து.

கள்ளம் கபடம் இல்லா வயது

சூதும் வாதும் வேதனை செய்யும். இது நாம் படித்த பால பாடம். மழலை வயது கள்ளம் கபடம் இல்லா வயது. இவ்வயதையே சூது வாத தெரியாத வயது என்பர். பிறரது வாழ்வின் வளர்ச்சிக்குத் தடை செய்யும் எண்ணம் வராத வயது. குழந்தைகளைக் கண்டால் குதூகலிக்கிறோம். குழந்தைகள் சூது வாத அறியாதவர்கள். சிரிப்பாரோடு சிரித்து மகிழ்ச்சியையும், அழுவாரோடு அழுது துக்கத்தையும் ஒரு சேர வெளிப்படுத்தும் பருவம் மழலைப் பருவம். கூட்டுப் புழுவாக இருந்த புழு பட்டாம் உச்சியாக சிறகடித்துப் பறக்கும் போது எந்த ஒரு மகிழ்ச்சி அடையுமோ அந்த மகிழ்ச்சி அடையும் பருவம்தான் மழலை பருவம். அந்த மழலைக்குச் சிறகடித்து பறக்க மட்டுமே ஆசையாக இருக்கும். முடங்கி கிடக்க தோன்றாது. எப்போதும் சுறுசுறுப்பாக இயங்கி கொண்டே இருக்கும். எதற்கெடுத்தாலும் தானும் மகிழ்ந்து பிறரையும் மகிழ வைக்கும் உன்னத பருவம். இதைத் தான் இவ்வாறு கூறுகிறோம்.

குழலிசையும், யாழிசையும்

தோற்றுப் போயின - உன்

நஞ்சில்லா நன் மொழியால்!

உடல் வளர்ச்சி குறைந்த வேகத்தில் அமைந்தாலும், கற்றுக் கொள்ளும் ஆர்வத்தோடு மன உறுதியுடன், இளம் கன்று பயம் அறியா என்பதற்கிணங்க பயம் அறியாமல் பட்டாம் உச்சியாய் சிறகடித்து தன் உணர்வுகளை உடனுக்குடன் வெளிப்படுத்தும் பருவம் துடிப்பாய் துணிந்து செய்யும் பருவம் தான் மழலைப் பருவம்.

‘பச்சை மரத்தில் அடிக்கும் ஆணியாய் பளிச்சென பதியும் சின்னப் பருவம்

பெற்றோர் உற்றார் அமையும் விதத்தில் வளர்ந்து வரும் பேதைப் பருவம்'

மழலையின் வெற்றிக்குப் பங்களிக்கும் காரணிகள்

1. பெற்றோரின் ஊக்கமும், ஆதரவும்.

மழலை சரியாக செய்யும் செயலை ஊக்கப்படுத்தினாலே மகிழ்வோடு வளரும். எந்தக் கடினமான செயலை முயற்சித்தாலும் தன்னோடுகூட பெற்றோர் இருக்கிறாரே என்ற ஆதரவு அக் குழந்தை பயம் நீங்கி தன்னம்பிக்கையோடு, சுதந்திரமாக வாழ வழி வகுக்கிறது. குழந்தைகளைத் தவறு செய்ய அனுமதிப்பது, அவைகளிடமிருந்து குழந்தைக்குத் தவறைச் சரி செய்யும் குணத்தைக் கற்றுக் கொடுப்பது பாதுகாப்பான எல்லைக்குள் அவர்களின் சுற்றுப்புறங்களை ஆராய அனுமதிப்பது, அவமான உணர்வை வளர்க்காமல் தானாக இயங்கும் உணர்வை வளர்க்க உதவி செய்கிறது. எல்லா நிலைகளிலும் மழலையிடம் பொறுமையோடு காரணங்களை விளக்கினால் புரிந்து கொண்டு பொறுப்புணர்வோடு வளர்வார்கள்.

கருவிலிருந்து குழந்தைகளின் அனைத்து பருவத்திலும் உடனிருந்து, நல்ல உறுதுணையாய் இருப்பவர்கள் பெற்றோர், பண்படுத்திய நிலத்தில் தேர்ந்த பயிர் விளைவது போல் குழந்தைகளின் மனதில் பெற்றோர் நல்ல பகிர்வுகளை உருவாக்கினால் எதிர்காலத்தில் அவர்களிடம் நல்ல விளைவுகள் உருவாகும். இளமையில் கற்றுக் கொடுப்பது உளவியல் ரீதியாக குழந்தைகளின் மனதில் நல்ல பதிவை உருவாக்கும்.

2. பகிர்வும் பங்களிப்பும்

குழந்தைகளின் முதல் பகிர்வு தாயின் கருவறையிலேயே தொடங்குகிறது. இரண்டாவது பகிர்வு குழந்தை பிறப்பிலிருந்து வாழ்நாள் முழுவதும் தொடர்கிறது. பெற்றோரின் பங்களிப்பே குழந்தைகளின் ஆதார நாதம். ஏனெனில் குழந்தைகளின் பன்முக வளர்ச்சி பெற்றோரிடமிருந்து பெறப்படுகிறது. கருத்துச் செறிவான தாலாட்டுப் பாடலில் துவங்கி பண்பாடு, கலாச்சாரம், நீதி, வீரம் என அனைத்தையும் வெளிப்படுத்தும் கதைகள், குழந்தைகளின் விளையாட்டு, வீட்டு வேலையில் பகிர்வு என அனைத்துச் செயல்களிலும் பெற்றோர்கள் மற்றும் பெரியவர்கள் தங்களுடைய பகிர்வையும், பங்களிப்பையும் குழந்தைகளுக்கு அளித்தனர். அதனால் குழந்தைகள் உளவியல் ரீதியாக உடல்நலத்தோடு, மனப்பலத்தையும் பெற்றனர். இன்று காலச் சூழலால் கூட்டுக் குடும்பம் மாறி தனித்து வாழும் குடும்பம் உருவாகியுள்ளது. அன்பையும், பண்பையும், பணியையும், அரவணைப்பையும் கற்றுக் கொடுத்த கூட்டுக் குடும்பம் குறைந்து விட்டதால் பெற்றோரின் அதிகமான பகிர்வு இன்றைய குழந்தைகளுக்குத் தேவைப்படுகிறது.

குழந்தைகளின் உளவியல் பிரச்சனைகள்

மழலை குழந்தைகளுக்கு உளவியல் ரீதியாகப் பல பிரச்சனைகள் ஏற்படுகின்றன. அக் காரணிகள் அவர்கள் வாழ்வின் வளர்ச்சியை பாதிப்பதையே செய்கிறது. தொடர் தோல்விகளால் ஏற்படும் மன அழுத்தம், அதற்காக தண்டிக்கப் பட்டால் அவமான உணர்வு, மழலையின் விருப்பத்தை பெற்றோர் அல்லது பெரியவர்கள் நிராகரித்தல், பிறரின் எதிர்மறையான விமர்சனங்கள், மழலைகளின் மனதைப் பாதித்து அது அவர்களின் வாழ்வின் வளர்ச்சிக்குப் பிரச்சனையாக உருவெடுக்கிறது.

தேவையும் நிராகரிப்பும்

இன்றைய சூழலில் பெண்களும் வேலைக்குச் செல்வதால் உறவுகளைச் சந்திக்கும் நேரம் குறைந்து விட்டது. கிடைக்கும் நேரத்தில் கணினி, அலைபேசி, தொலைக்காட்சியுடன் நேரம் செலவிடப்படுகிறது. காலத்தே செய்யாத காரியத்தால் எந்தப் பயனும் இல்லை. கிடைக்கும் நேரத்தில் குழந்தைகளின் மனநிலை அறிந்து தகுந்த நேரத்தில் பகிர்வையும், பங்களிப்பையும் கொடுத்தால் பாதுகாப்பான சூழல் உருவாகும். குழந்தைகளை உருவாக்கும் போது தேவையானதைக் கொடுத்து தேவையற்றவைகளை நிராகரிக்கக் கற்றுக் கொண்டால் எதிர்காலத்தில் மாற்றங்களால் ஏற்படும் ஏமாற்றங்களை எதிர்கொள்வதற்குப் பக்குவப்படுவார்கள்.

வெறுப்புணர்வு

மழலைக் குழந்தை வெறுப்புணர்விற்கு ஆளாவது முதல் குழந்தை இருக்கும்போது இரண்டாவது பிரசவத்திற்குத் தாய் தயார் ஆவது, முதல் மனைவி இருக்கும்போது இரண்டாவது மனைவியைத் திருமணம் செய்ய ஒரு கணவன் முயற்சி செய்வது போன்றது. அச்செயல் முதல் மனைவியின் மனதில் என்ன உணர்வுகளைத் தோற்றுவிக்குமோ அதே உணர்வுகளை முதல் குழந்தையின் மனதில் தோற்றுவிக்கும். தனக்கு இருக்கும் முக்கியத்துவம் பறிபோவதை எந்தக் குழந்தையும் விரும்புவதில்லை. அதே நேரத்தில் புதியக் குழந்தையைக் கவனிக்கும் விசயத்தில் காட்டும் அக்கறையை முதல் குழந்தையையும் கவனிக்கும் நேரத்தில் பெற்றோர்களும், வீட்டில் உள்ள மற்றவர்களும் உறவினர்களும் காட்டுவதில்லை. இதனைக் கவனிக்கும் முதல் குழந்தை இதுவரை எனக்கு முழுமையாக கிடந்து வந்த கவனிப்பைப் பறித்துக் கொண்டது புதிதாக வந்தக் குழந்தை தானே என நினைத்து அக்குழந்தையின் மீது வெறுப்பையும் பொறாமையையும் வளர்த்துக் கொள்கிறது.

நல்லுறவு நீடிக்கும்

பெற்றோர்கள் தங்கள் குழந்தைகளை சமமாக நடத்தும் போது குழந்தைகளிடையே சகோதர பாசம் அதிகரித்து நல்லுறவு நீடிக்கும். உடன் பிறந்தோரிடம் நிலவும் இந்நல்லுறவு இரு குழந்தைகளின் மொழி வளர்ச்சி, அறிவு வளர்ச்சி ஆகியவற்றிற்கு துணை நிற்கும். அன்பு பாசம் ஆகியவற்றின் ஆதாரமாக அமையும். விளையாட்டு, நகைச்சுவையுணர்வு ஆகியவற்றை வளர்க்க உதவும்.

முடிவுரை

அன்பு மொழிப் பேசும் மழலையைக் கையாளும் விதத்தை அறிந்த நாம் எதையும் எளிதில் புரிந்து, எளிதில் மறந்து, அனைவரையும் கவர்ந்து, உறவை இணைத்து, தன் புன்சிரிப்பால் எல்லோரையும் மயங்கவைக்கும் மழலையைப் பாசத்தோடு, கரிசனையோடு, உறவோடு வாழ வைப்போம். அதுவே அவர்களின் சிறந்த எதிர் காலத்துக்கும், தன்னம்பிக்கையான வளர்ச்சிக்கும் வழிவகுக்கும். நேர்மறை எண்ணங்களை வளர செய்து, எப்போதும் மகிழ்ச்சியாய் இருந்து பிறரையும் மகிழ்விக்க பழக்குவோம்.

துணை நூற்பட்டியல்

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திருமந்திரம் கூறும் யோக நெறியும் ஆரோக்கிய வாழ்வும்

ஆன்சிமோள் சி.

தமிழ்த்துறை (சுயநிதி), ஹோலிகிராஸ் கல்லூரி (தன்னாட்சி), நாகர்கோவில் - 629 004
மனோன்மணியம் சுந்தரனார் பல்கலைக்கழகம், திருநெல்வேலி - 627 012

கட்டுரைச் சுருக்கம்

திருமூலரின் திருமந்திரம், தமிழ் சித்தர் மரபின் முக்கிய நூலாகக் கருதப்படுகிறது. இது யோக நெறி, ஆன்மிக வளர்ச்சி, ஆரோக்கியம், மற்றும் உடல்-மன உறவுகளை அடிப்படையாகக் கொண்டது. உடலின் அழுக்குகளை நீக்குவதே யோக நெறியின் முதல் கட்டமாகும். சரியான ஆசனங்கள் மற்றும் பிராணாயாமம் உடலை புனிதமாக்கும். தியானம் மற்றும் பிராணாயாமம் மன அமைதியைப் பாதுகாக்கிறது. மன அழுத்தம் மற்றும் கலக்கம் குறைக்கிறது. உடல் ஆரோக்கியமே ஆன்மிக முன்னேற்றத்தின் அடிப்படையாகக் கூறப்படுகிறது. உணவின் பக்தி, நன்னடத்தையும் ஆன்ம சுத்தத்தையும் வலியுறுத்துகிறது. திருமந்திரத்தில் கூறப்பட்ட யோகப் பயிற்சிகள் மற்றும் ஆரோக்கிய வழிமுறைகள், நவீன மருத்துவத்துடன் இணைந்து, இன்று மனஅழுத்தம், உடல் சோர்வு போன்ற பிரச்சனைகளுக்கு தீர்வு அளிக்கின்றன. திருமந்திரம் யோக நெறி மற்றும் ஆரோக்கியம் பற்றிய விரிவான கற்றல், மனித வாழ்க்கையை முழுமையாக்கும் ஒரு ஆன்மிக வழிகாட்டியாக இன்றைய வாழ்வில் பயன்பாடாக திகழ்கிறது.

முன்னுரை

சித்தர் பாரம்பரியத்தில் தோன்றிய திருமூலர், அறுபத்துமூன்று நாயன்மார்களின் ஒருவராவார். இவர் இயற்றியருளிய திருமந்திரம் பத்தாம் சைவத் திருமுறையாகப் போற்றப்படுகின்றது. திருமூலரின் திருமந்திரம் மெய்ஞ்ஞானத் தத்துவங்களோடு சிறந்த மருத்துவக் கோட்பாடுகளையும் கொண்டு இயங்குகிறது. திருமந்திரத்தில் யோகமானது உடல், உயிர், உள்ளம், சமூகம் இவற்றின் ஆரோக்கிய வாழ்வுக்கு வழிவகுக்கின்றது. மன ஆரோக்கியமே சுகவாழ்வுக்கு அடிப்படையாகிறது. இவற்றைப் பற்றி திருமூலரின் பாடலில் ஆராய்வதே இக்கட்டுரையின் நோக்கமாகும்.

இமயம்

“கொல்லான் பொய்கூறான் களவிலான் எண்குணன்
நல்லான் அடக்கமுடையான் நடுச்செய்ய
வல்லான் பகுந்து உண்பான் மாசிலான் கட்காமம்
இல்லான் இயமத்திடை நின்றானே - (திருமந்திரம் - 554)

இப்பாடலில் வரும் நல்லொழுக்கங்களே இயமம் எனப்படுகின்றன. இந்நெறிகள் மன ஒருமைப்பாட்டுக்கு வழிவகுக்குமெனத் திருமூலர் கருதினார். மனிதனுக்கு ஏற்படும் உடல் தாக்கத்தைவிட உள்ளத்தாக்கமே ஆபத்தானது. உள்ளத்தாக்கத்தால் உடல் நோய்கள் ஏற்பட வாய்ப்பு உள்ளது. மனிதனுக்கு ஏற்படும் நோய்களான அதிகருதி அழுக்கம், நரம்புத்தளர்ச்சி என்பன மேற்கூறிய காரணங்களினால் ஏற்படுகின்றன. இப்பாடலில் குறிப்பிடும் எதிர்காரணங்களால் மனிதனின் உடல்நிலையிலும் உளநிலையிலும் சமநிலை

பாதிப்படைகின்றன. மனதில் ஏற்படும் குழப்பம், அமைதியின்மையால் இரப்பையில் அமிலம் அதிகமாகச் சுரக்கப்படுகிறது. இதனால் குடற்புண், நித்திரையின்மை ஏற்படுகின்றன. மேலும் மனநோய் ஏற்படவும் வாய்ப்புள்ளது. மனிதனுக்கு நோயற்ற வாழ்வே குறைவற்ற செல்வமாதலால் திருமூலர் இமயநெறியை மக்களுக்குப் போதித்து அந்நெறியில் நிற்போர் இறைவன் திருவடிநிழல் சேர்வர் என்று உயர்வு நெறியைப் பாடலில் கூறினார் எனலாம்.

நியமம்

நியமம் என்பது நற்செயல் எனப் பொருள்படும் நல்லனவற்றைச் செய்து ஒழுகுதலே நியமம் என்றார் திருமூலர். இவற்றோடு தூய்மை, அருளுடைமை, ஊன் சுருக்கம், பொறுமை, செம்மை, வாய்மை, உறுதி என்ற நெறிகளில் ஒழுகுதலும் கொலை, களவு, காமம் ஆகியவற்றிலிருந்து நீங்குதலும் நியமம் எனப்படுகிறது.

“தவழ்செயஞ் சந்தோஷம் ஆதீவிகம் தாணஞ்
சிவன்றன் விரதமே சித்தாந்த வேள்வி
மகஞ்சிவ பூசையொண் மதிக்கொல்வீர் ஐந்து

நிலம் பலசெய்யின் நியமத்தன்னானே” - (திருமந்திரம் - 557)

இப்பாடலில் மனதின் எண்ணங்களே செயல்களாக மாறுவதால் நற்சிந்தனை இருப்பின் நல்லொழுக்கம் ஏற்படுகின்றது. பதஞ்சலி முனிவர் இதனைச் சுவாத்தியாயம் என்றார்.

தியானம்

தியானம், மனிதனை நிதானப்படுத்தி அவனது உணர்ச்சிகளைச் சீர்ப்படுத்தி அவனை நிலைத்திருக்கச் செய்கின்றது. இது தன்னடக்கமாகும். சுத்தமான, காற்றுள்ள, அமைதியான, இயற்கையோடு இணைந்த, மனத்தைச் சஞ்சலப்படுத்தாத இடத்தில் ஒரு மெத்தையில் அமர்ந்து எரியும் பசுநெய் விளக்கை உற்றுநோக்கிய வண்ணம் பிரணாயாமம் செய்வதே தியானமாகும். தியானத்தில் ஏற்படும் மனவளர்ச்சியைத் திருமூலர் படி முறைகளாகக் காட்டுகிறார்.

முதல்படி முறையில் மனதில் அடித்தளத்தில் புல் எரிதல்போன்று மெல்லிதாக ஒரு ஒளி தோன்றும். இரண்டாம்படி முறையில் தீபந்தம் எரிவதுபோன்று இருக்கும். தீபந்தத்தில் ஒளியும் புகையும் நன்கு தெரியும். மனவளர்ச்சி கூடியிருக்கும். மூன்றாம் படிமுறையில் தூண்டாமணி விளக்குப் போன்று அகத்தே ஒளி எரியும். மனத்தின் அடித்தளத்தில் சுடர் விட்டு ஒளி பிரகாசிக்கும். வாழ்க்கையில் சஞ்சலம் ஏற்படா மனநிலை ஏற்படும்.

மனமும் உடலும் நோய்க்குரிய காரணிகளில் ஒன்றாகும். எனவே தியானத்தால் மனதைக் கட்டுப்படுத்தி உடலை ஆரோக்கியமாக வைத்திருக்கும் வழிமுறைகளைத் தியானம் மூலம் திருமூலர் காட்டுகிறார்.

தியானம் ஒரு மனிதனது உணர்ச்சிகளைச் சீர்ப்படுத்தி அவனை நிலைத்து நிற்கச் செய்வது திருமூலர் இதனை,

“நாட்டம் இரண்டும் நடுமூக்கில் வைத்திடில்
வாட்டமும் இல்லை மனைக்கும் அழிவில்லை
ஓட்டமும் இல்லை உணர்வில்லை தூனில்லை
தேட்டமும் இல்லை சிவன் அவன் ஆமே

- (திருமந்திரம் - 604)

பார்வையை மூக்கு நுனியில் வைத்து பிராணனை உள்ளே அடக்கி, அசையாமல் நின்று தியானிப்பவர்களுக்கு அழிவில்லை என்றும் அத்தகு ஆன்மாக்களும் இறைவனோடு ஒன்றித்து நிற்கும் என்றும் கூறப்படுகிறது.

ஆசனம்

உடலை ஓம்பும் வழிகளில் ஆசனமும் ஒன்றாகும். ஆசனம் என்பது ஒரு அற்புதமான ஆன்மீக ஒழுக்க நெறியாகும். ஒவ்வொருவகை ஆசனமும் உடலில் ஒவ்வொரு உறுப்பையும் வலிமையடைய செய்கிறது. ஆசனம் உடலுக்கும் உள்ளத்துக்கும் தேவையான உறுதியைக் கொடுத்து நீண்ட ஆயுளுக்கு வழிவகுக்கிறது. புலன்களைத் திறமையாகத் தொழிற்படச் செயல்படவும் புலன்களுக்கு அடிமையாகாமல் தடுக்கவும் உதவுகின்றது. இளைஞர்கள் அறிவை வளர்க்கவும் உடலின் உள்ளுறுப்புகளை மென்மையாக்கி அவற்றின் செயலாற்றலைப் பெருக்கி நோய் ஏற்படின் அவற்றைப் போக்கவும் நுணுக்கமான பணியைச் செய்கின்றது. இரத்த அழுக்குகளை வெளியேற்ற தூண்டுகின்றது. பத்மம், கோமுகம், பங்கயம், கேசரி, சொத்திரம், வீரம் சுகாதனம் ஆகிய ஏழு ஆசனங்களையும் அவற்றின் செய்யும்முறை, கடைபிடிக்க வேண்டிய விதிமுறைகள் என்பனவற்றைத் திருமூலர் திருமந்திரத்தில் கூறப்படுகின்றன.

யோக மார்க்கமும் ஆரோக்கிய வாழ்வும்

திருமூலர் கூறும் யோக மார்க்கம் மனத்தோடு தொடர்புடையது. ஆரோக்கியத்தைப் பேண மணமும் ஒரு காரணியாகிறது. பொதுவாகச் சரீரம் தாக்கப்பட்டால் மனமும் மனம் தாக்கப்பட்டால் சரீரமும் நோய்க்கிடனாகின்றன. எனவே தான் இயமநெறியிலே தீயனவற்றைச் செய்யாது ஒழுகுதலையும் நியமநெறியில் ஊன்சுருக்கம் கூறப்படுகிறது. வள்ளுவர் மருத்துவம் என்ற அதிகாரத்தில் இதே கருத்தைக் கூறினார்.

சமாதி

“பரம்பொருளோடு இரண்டறக் கலந்த நிலையே சமாதி என்கிறது அதர்வேதம். ஆனால் திருமூலர்,

“கற்பனை யற்றுக் கனல்வழியே சென்று

சிற்பனை எல்லாம் சிருட்டித்த பேரொளிப்

பொற்பினை நாடிப் புணர்மதி யோடுற்றுத்

தற்பரமாகத் தகுந்தண் சமாதியே”

- (திருமந்திரம் - 628)

எனவும், மேலும்

“மன்மனம் எங்குண்டு வாயுவுமங்குண்டு

மன்மனம் எங்கில்லை வாயவ மங்கில்லை

மன்மனத் துள்ளே மகிழ்ந்திருப் பார்க்கு

மன்மனத் துள்ளே மனோலய மாமே”

என்று விளக்கம் கூறதல் கவனிக்கத்தக்கது. ஒருவன் பல்வகைத் துன்பங்களையும் நீக்கி. அத்துன்பங்கள் தொடர்ந்து வருவதற்குக் காரணமாகவுள்ள மாயை கெடத்தவ நிலையில் பரம்பொருளை அடையலாம் என்கிறார். மேலும் மேலைவாசல் வெளியுலகம் கண்ட பின் காலன் வார்த்தை கனவிலும் இல்லையே என்றும் சமாதியில் எண்ணெட்டுச் சித்தியும் எய்துமே என்றும் கூறுவதால் சமாதியில் ஏற்படக் கூடிய பயன்களையும் உணரக் கூடியதாகவுள்ளது.

முடிவுரை

திருமூலரின் பாடல் வழி மனித உடலின் தொழிற்பாட்டையும் இமயம், நியமம், தியானம், யோக மார்க்கவும் ஆரோக்கிய நெறிமூலம் துன்பங்கள் நீங்கி நிறைந்த இன்ப வாழ்வும் பரம்பொருளின் கிருபையும் கிடைக்க வாய்ப்பாகிறது என்பது மேலே கூறிய கருத்துக்கள் மூலம் அறிய முடிகிறது.

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பழமொழி நானூற்றில் கல்விச் சிந்தனைகள்

டெய்சிபாய் சா.

தமிழ்த்துறை (சுயநிதி), ஹோலிகிறாஸ் கல்லூரி (தன்னாட்சி), நாகர்கோவில் - 629 004
மனோன்மணியம் சுந்தரனார் பல்கலைக்கழகம், திருநெல்வேலி - 627 012

கட்டுரைச் சுருக்கம்

பழமொழி நானூற்றில் மானிட வாழ்வின் பல்வேறு அம்சங்கள் பற்றிய சிந்தனைகள் இடம்பெற்றுள்ளன. குறிப்பாகக் கல்வி, அறிவு, ஒழுக்கம், வாழ்வியல் நிலை பற்றிய பல அறிவுரைகளும் நெறிப்பாடுகளும் வழங்கப்படுகின்றன. கல்வி ஒளியை வழங்கும், முயற்சி வெற்றிக்குத் தூண்டல் போன்ற கருத்துகள் இந்நூலில் இடம்பெற்றுள்ளன. கல்வியின் மூலம் கிடைக்கும் அறிவு வாழ்க்கையைச் செம்மையாக்குவதோடு சமூகத்தில் உயர்ந்த இடத்தைப் பெறவும் உதவுகிறது. பழமொழி நானூறு கல்வியின் பயன்களையும் ஆழமான சிந்தனைகளையும் எளிய முறையில் எடுத்துரைக்கிறது.

முன்னுரை

மனிதனின் அறிவாற்றலை மேம்படுத்திக் கொள்ள உதவுவது கல்வி. 'கல்' என்ற சொல்லில் இருந்து கற்றல் தோன்றியிருக்கலாம். கல்வியின் மேன்மையையும் கற்றலின் சிறப்பினையும் அறிலக்கியங்கள் குறிப்பிடுகின்றன. அவற்றுள் பழமொழிநானூறு கல்வியின் முக்கியத்துவத்தையும் கற்றவர் அடையும் பயன்களையும் மிகத் தெளிவாக எடுத்தியம்புகிறது. பழமொழிகள் மனித வாழ்க்கையைச் செம்மைப்படுத்துவன. நம் முன்னோர்களின் அனுபவக் குரல்களே பழமொழி என்றால் அது மிகையாகாது. முன்னுரை அரையனார் இயற்றிய பழமொழி நானூற்றில் குறிப்பிடப்பட்டுள்ள கல்விச் சிந்தனைகளை வெளிப்படுத்துவது இக்கட்டுரையின் நோக்கமாகும்.

கல்வியின் மேன்மை

நூல் பலகற்றுச் சிறந்தவர்கள் அறிவுடையவர்கள். அவ்வறிவுடையார் புகழ் நாற்றிசையும் சென்று பரவாத நாடில்லை. அந்நாடுகள் அவர்களுக்கு வேற்று நாடுகள் ஆகாது. சொந்தநாடாக விளங்கும். அவர்கள் செல்லும் வழிகளுக்குக் கட்டுச்சோறு கொண்டுசெல்ல வேண்டியதில்லை. அந்நாளில் பயணம் மேற்கொள்பவர்கள் கட்டுச்சோறு கொண்டுசெல்வது வழக்கம். இப்பெருமை யாவும் அவருக்குக் கல்வியினால் கிடைத்த பெருமையே என்பதை,

“ஆற்றவும் கற்றார் அறிவுடையார் அ.துடையார்

நாற்றிசையும் செல்லாத நாடில்லை அந்நாடு

வேற்று நாடாகா தமவேயாம் ஆயினால்

ஆற்றுணா வேண்டுவ தில்”

(பழமொழி – 55)

என்னும் பாடலில் குறிப்பிடுகிறார்.

மேலும் வள்ளுவரும் கல்வியின் மேன்மையை,

“விலங்கொடு மக்கள் அணையர் இலங்குநூல்

கற்றாரோடு ஏனை யவர்”

(குறள் - 410)

என்னும் குறளில் கற்றலின் மேன்மையைக் குறிப்பிடுவதோடு கல்லாதவரை விலங்குகளுடன் ஒப்பிட்டுக் கூறுவதைக் காணமுடிகிறது. நீதி இலக்கியங்கள் மட்டுமின்றி சங்ககாலத்திலும் கல்வியின் இன்றியாமையை பல பாடல்கள் புலப்படுத்துகின்றன.

பெற்றோர் தரும் கல்வி

தாய் தன் குழந்தையை ஈன்று அதனைப் பேணி வளர்க்கின்றாள். குழந்தையின் நலனில் அதிக அக்கரைக் கொள்கிறாள். தந்தையாயின் தன் குழந்தையை அறிவுமிக்கச் சான்றோனாக்க விளைகிறார். இக்கருத்தை,

“ஈன்று புறந்தருதல் எந்தலைக் கடனே

சான்றோன் ஆக்குதல் தந்தைக்குச் கடனே” (புறம் - 312)

என்னும் புறநானூற்றுப் பாடலால் அறிய முடிகின்றது. சிலைவடிக்கும் சிற்பிக்குத் தான் தெரியும் தான் செய்த பாவை பின்நாளில் அனைவரும் வணங்கும் தெய்வமாகும் என்று. அதுபோல நன்னெறி புகட்டி வளர்த்த தந்தைக்கு மட்டுமே தெரியும் தன் மகன் பார்போற்றும் உயர்ந்த நிலையினை அடைவான். அவன் கற்ற கல்வியே அவனுக்கு அணங்காகும். இக்கருத்தை பழமொழிநானூறு மிகவும் அழகாக குறிப்பிடுகிறது.

அரசர் பெறும் கல்வி

பழங்காலத்தில் முடிஆட்சி செய்த அரசன் மேன்மைக்கு உரியவனாக விளங்கினான். குடிமக்களைக் காக்கும் பெரும் பொறுப்பு அரசனைச் சார்ந்திருந்தது. அரசன் தன்னை நம்பியுள்ள குடிமக்களைத் துன்புறுத்தி அவர்களிடமிருந்து இறைபொருளை அதிகமாகப் பெற்று அக்குடிமக்களுக்கு உதவுதல் என்பது மயிலினது உச்சிக் கொண்டையை அறுத்து, அதற்கு உணவாக அதன் வாயில் போடுவதற்கு ஒப்பாகும். துன்புறுத்தி அதிகவரி வாங்கிய அரசர் பின்பு என்ன உதவிகள் செய்தாலும் மக்கள் அதனை ஏற்பதில்லை. அரசன் குடிமக்களை வருத்தாது காப்பது கடமையாகும். இதனை, “கூட்டறுத்து வாயில் இடல்” என்னும் பழமொழியால் உணரப்படுகிறது. குறளும் இக்கருத்தினை,

“வேலொடு நின்றான் இடுஎன் றதுபோலும்

கோலொடு நின்றான் இரவு” (குறள் - 552)

என்னும் குறளில் குறிப்பிடுகிறார். மேலும் குடிமக்களைப் பேணாது துன்புறுத்தும் அரசன் எமனைப் போன்றவன். பகைவரிடத்து கொடியவனாக விளங்கும் அரசன் தன் குடிகளிடத்தில் அருள் உள்ளவனாக நடக்கவேண்டும் என்பதனை,

“செங்கோண்மை வேந்தர்க்கண் வேண்டும் சிறிதெனினும்

தண்கோல் எடுக்குமாம் மெய்” (பழமொழி— 210)

நல்ல கொடைப் பண்பு, செங்கோல் முறைமையும் கொண்ட சிறந்த அரசனாக இருப்பினும் பகைவர்களை எதிர்த்துச் சிதறி ஓடும்படி செய்து வெற்றி கொள்ளாத அரசன் தன் படைக்கலன்களை வைத்து அழகுபார்ப்பது நல்லதாகும் எனப் போரிடா அரசனின் இழி நிலையையும், பகைவர் பலர் கூடி தம்மை எதிர்த்து வந்தக் காலத்தில் அரசனானவன் ஒருவனாயின் வீழ்ந்துவிடக் கூடும். ஆதலால் தன் படை வலிமையைப் பெருக்கிக் கொள்வது நல்லதாகும் என அரசனுக்குரிய கல்வியைப் பழமொழிநானூறு போதிக்கிறது. அரசன் வரி வாங்கும் முறையினை வண்டினம் பூவைச் சிதைக்காது அதிலுள்ள தேனைக் குடிப்பது போல

குடிமக்களை வருத்தாது காலமறிந்து பக்குவமாக வரி வாங்க வேண்டும் என்பதையும் இந்நூல் குறிப்பிடுகிறது.

அறிவிலிக்குப் புகட்டும் கல்வி

முடர்க்குப் புகட்டும் கல்வி வீணானது. அறிவுடையோர் என்றும் புல்லறிவு கொண்ட முடர்களுக்கு உபதேசம் செய்வதற்கு முயலக்கூடாது. உடலளவில் மனிதனாக விளங்கும் முடர்களுக்கு, உறுதிப்பொருள் பற்றிச் கூறுவது கடலினுள் மாம்பழத்தைக் கொட்டுவது போன்றது. அது பயனற்ற செயலாகும். இதனை,

“உடலா ஒருவற்கு உறுதியுணர்த்தல்

கடலுளால் மாவடித் தற்று” (பழமொழி— 120)

என்னும் பழமொழியால் விளக்கியுள்ளார். நன்னீர் பாயும் ஆறுகள் மிகுதியான வெள்ளப் பெருக்குடன் கடலில் நீரைப் பாய்ச்சினாலும் கடல் நீரின் உப்புத் தன்மை மாறுவதில்லை. அதனைப் போல் நல்லவர் தொடர்பு கீழோர் பெற்றிருப்பினும் அவர் நல்லவராக மாட்டார். முடர்களைக் கல்வி போதித்து அறிவுடையோர் ஆக்க இயலாது. தட்டுவர் இல்லாது போயின் துடியினின்று பண் எழுவதில்லை. அதுபோல் அறிவுறுத்துவார் இன்றி அறிவிலியரின் அறிவும் செயல்படாது, அவர் கற்றும் பயனில்லை, அவருக்குக் கற்பிப்பதும் வீணாகும். இதனை, “கற்றறிவு போகாகடை” என்னும் பழமொழி குறிப்பிடுகிறது.

வாழ்க்கைக் கல்வி

வாழ்க்கைக்குரிய கல்வியைப் புகட்டும் நீதிநூல்கள் பல உள்ளன. இந்நூல்கள், சிறந்த வாழ்க்கைக்குத் தேவையான அறத்தை கடைப்பிடிக்கவும், வாய்மையைக் காக்கவும் ணேடிய வழிமுறைகளைப் போதிக்கின்றன.

“இல்வாழ்க்கை யானும் இலதானும் மேற்கொள்ளார்

நல்வாழ்க்கை போக நடுநின் எல்லாம்

ஒருதலையாச் சென்று துணியா தலரே

இருதலையும் காக்கழித் தார்” (பழமொழி— 46)

ஒருவன் தனக்குக் கேடுவருகின்ற காலத்திலும் பிறருக்குத் துன்பந்தராத செயல்களைத் தான் செய்ய வேண்டும். பெரிய மலைகள் கூட ஒருகாலத்தில் தேய்ந்து போகலாம். ஆனால் நாம் செய்கின்ற தீயச்செயல்கள் அதன் விளைவுகள் என்றும் வழிவழியாகத் தொடர்ந்து வரும். இதனை வள்ளுவரும்,

“தீயினாற் சுட்டபுண் உள்ளாரும் ஆறாதே

நாவினாற் சுட்ட வடு” (குறள் - 129)

எனக் கூறியுள்ளார். தீயச்செயல்கள் செய்தலைக் காட்டிலும் சாதலே மேலானது எனப் பழமொழிநானூறு உரைக்கின்றது.

முடிவுரை

மக்களின் வாழ்க்கைக்குத் தேவையான நல்ல கருத்துக்களைப் போதிப்பதில் பழமொழிநானூறு பெருமை பெற்ற நூல் என்பது திண்ணம். பழங்காலச் சூழலுக்கு ஏற்ப நீதியையும், அந்நீதியின் வழி நல் அறிவுறுத்தலாகிய கல்வியையும் இந்நூல் புகட்டுகிறது. அரசருக்கும், அவரின் போர்ச்சூழலுக்கும், அறிவற்ற முடருக்கும் மக்களின் வாழ்க்கைச்

சூழலுக்கும் ஏற்றக் கல்வியை அறிவுரையாக இந்நூல் வழங்கியுள்ளது. கற்றலினால் மேன்மை பெற முடியும் என்பதையும், கற்றவருக்குக் கிடைக்கும் பெருமதிப்பையும் இந்நூலின் மூலம் முன்றுரை அரையனார் மிகத் தெளிவாக எடுத்துரைக்கின்றார்.

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முல்லைப்பாட்டில் திணைக்கோட்பாடு

தேன்மொழி செ.

தமிழ்த்துறை, ஹோலிகிராஸ் கல்லூரி(தன்னாட்சி), நாகர்கோவில் - 629 004

மனோன்மணியம் சுந்தரனார் பல்கலைக்கழகம், திருநெல்வேலி - 627 012

கட்டுரைச் சுருக்கம்

தமிழின் பழம்பெருமைக்குச் சான்று பகரும் தொல்காப்பியமும் சங்கஇலக்கியங்களும் இண்டாயிரம் ஆண்டுகளுக்கு முற்பட்ட தமிழின் முதல் இலக்கண இலக்கிய நூல்களாகும். தொல்காப்பிய இலக்கணத்தின் அடிப்படையில் அமைந்துள்ள இலக்கியங்கள் தான் சங்க இலக்கியங்கள். சங்க இலக்கிய வகைமைகளில் ஒன்றான பத்துப்பாட்டு இலக்கியங்களில் ஒன்று முல்லைப்பாட்டு. நப்பூதனாரால் பாடப்பட்ட இவ்வகப்பாடல் 103 அடிகளைக் கொண்டதாகும். ஐந்திணைகளில் ஒன்றான முல்லைத்திணையில் அமையப்பெற்ற இப்பாடல் அகக்கோட்பாட்டுடன் ஒப்பிட்டு ஆராயப்பட்டுள்ளது.

முன்னுரை

சங்க இலக்கியத்தில் முழுவதும் முல்லைத்திணையை மையமாக வைத்துப் படைக்கப்பட்ட இலக்கியம் பத்துப்பாட்டில் இடம்பெற்ற முல்லைப்பாட்டாகும். ஐந்திணை உரிப்பொருட்களில் கற்புக்குரியதாகக் கொண்டாடப்படுவது முல்லைத்திணைக்குரிய இருத்தலாகும். இத்தகைய சிறப்புக்குரிய முல்லைத் திணையில் அமையப்பெற்ற முல்லைப்பாட்டு அகத்திணைக் கோட்பாட்டுக்குப் பொருந்தியுள்ள விதத்தைக் கண்டறிவதே கட்டுரையின் நோக்கமாகும்.

அகத்திணைக் கோட்பாடு

அகத்திணைக்குரிய கோட்பாடுகளுள் முதன்மையானதும் மிக முக்கியமானதுமான ஒன்று பாட்டுடைத் தலைவர்கள் பெயர் குறிப்பிடப்படக்கூடாது என்பதாகும். இதனை

மக்கள் நுதலிய அகனைத் திணையும்

சுட்டிஒருவர் பெயர்கொளப் பெறாஅர் (தொல்-57)

எனும் நூற்பா வாயிலாக அறியலாம். அக இலக்கண மரபாகிய தலைமக்கள் பெயர் சுட்டலாகாது என்பதன் அடிப்படையில் முல்லைப்பாட்டில் ஓரிடத்தில் கூட தலைவன், தலைவியின் பெயர் சுட்டப் பெறவில்லை.

முதற்பொருள்

ஓத்த தலைவன் தலைவியிடையிலான அன்பைப் பற்றிக் கூறும் ஐந்திணைகளை முதல், கரு, உரிப் பொருள் என்று மூன்றாகப் பிரித்தனர். அவற்றுள்

நிலமும் பொழுதுமென முதலிரு வகைத்தே (நூற்பா-8)

என்று நம்பியகப்பொருளில் முதல் பொருள் வரையறுக்கப்படுகின்றது. முல்லைப்பாட்டின் தொடக்கமே முதல்பொருளைச் சுட்டுவதாக அமைந்துள்ளது.

நீர்செல நிமிர்ந்த மாஅல் போலப்

பாடு இமிழ் பனிக்கடல் பருகி, வலன்ஏர்பு
கோடு கொண்டு எழுந்த கொடுஞ்செலவு எழிலி
பெரும் பெயல் பொழிந்த சிறுபுன் மாலை (3-6)

எனும் பாடலடிக்கு ஒலிக்கின்ற குளிர்ந்த கடலின் நீரைக் குடித்து, வலமாய் எழுந்து, மலைகளில் தங்கிப் பின்பு உலகத்தை வளைத்துக் கொண்டு எழுந்த மேகமானது பெருமழை பெய்த மழைக்காலம் என்று பொருள். இதில் முல்லை நிலத்தின் பெரும் பொழுதான கார்காலமும் சிறுபொழுதான மாலையும் குறிப்பிடப்பட்டுள்ளது.

செறியிலைக் காயா வஞ்சன மல
முறியினர்க் கொன்னை றநன் பொன் காலக்
கோடற் குவிமுகை யங்கை யவிழத்
தோடார் தோன்றி குருதி பூப்பக்
கான நந்திய செந்நிலப் பெருவழி (93-97)

என்று கார்காலம், மலைக்காலத்தின் தன்மையும் இயல்பும் கூறி முல்லைநிலத்தை கண்முன் நிறுத்துகின்றார் நப்பூதனார்.

கருப்பொருள்

முதற்பொருளாகிய நிலத்தையும் காலத்தையும் அடிப்படையாகக் கொண்டு பிறக்கும் பொருள்களே கருப்பொருள்கள். இவை ஐவகை நிலத்திற்கும் இயற்கையாய் அமைந்தவை ஆகும்.

ஆரணங்கு உயர்ந்தோர் அல்லோர் புள் விலங்கு
ஊர்நீர் பூ மரம் உணா பறை யாழ் பண்
தொழில் எனக் கருசர் எழுவகைத்து ஆகும் (நூற்பா- 19)

என்று நம்பியகப்பொருள் கருப்பொருளைப் பட்டியலிடுகிறது. கருப்பொருளில் முதலில் இடம்பெறுவது தெய்வம் ஆகும்.

மாயோன் மேய காடுறை உலகம் (தொல்.-5)

என்று தொல்காப்பியர் முல்லை திணைக்குரிய நிலத்தைக் வரையறுக்கும் போது தெய்வம் சுட்டப்பட்டுள்ளதைப் போன்று

நனந்தலை யுலகம் வளைஇ நேமியோடு
வலம்புரி பொறித்த மாதாங்கு தடக்கை
நீர்செல நிமிர்ந்த மாஅல் போல (1-3)

எனும் அடிகளில் முல்லை நிலக்கடவுளான திருமால் பற்றி குறிப்பிடப்பட்டுள்ளதைக் காணலாம். முல்லைத்திணைக்குரிய மக்களைத் தொல்காப்பியர் பின்வருமாறு பட்டியலிடுகின்றார்.

ஆயர் வேட்டுவர் ஆடுஉத் திணைப் பெயர்
ஆவயின் வருஉம் கிழவரும் உளரே (தொல்.- 20)

என்கின்றார். நப்பூதனார் முல்லைப்பாட்டில்

உறுதுயர் அலமர னோக்கி யாய் மகள்
அடுங்குசுவ வசைத்த கையள் (13-14)

என்று முல்லைநில மக்களைப் பற்றிக் குறிப்பிடுகின்றார். மேலும் முல்லைப்பாட்டில் நாழி கொண்ட நறுவீ முல்லை

அரும்பு அவிழ் அலரி தூஉய்க் கைதொழுது (9-10)

கோடற் குளிமுகை யங்கை யவழி (95)

எனும் பாடலடிகளில் முல்லைத்திணைக்குரிய மலராகிய முல்லை இடம்பெற்றுள்ளதைக் காணலாம். மேலும் முல்லைத்திணைக்குரிய விலங்குகளில் ஒன்றான மான் பற்றி

திரிமருப் பிரலையொடு மடமானுகள(99)

என்று முல்லைப்பாட்டில் குறிப்புள்ளதைக் காணமுடிகின்றது. இவை மட்டுமன்றி முல்லைத் திணைக்குரிய உணவு, நீர், தொழில் போன்றவையும் முல்லைப்பாட்டில் இடம்பெற்றுள்ளதைக் காணமுடிகின்றது. முல்லைத்திணை உணவுகளில் ஒன்று வரகு ஆகும். இதைப்பற்றி

வானம் வாய்த்த வாங்குகதிர் வரகிற் (98)

என்று முல்லைப்பாட்டில் இடம்பெற்றுள்ளது. முல்லைநில மக்களான கோவலரின் தொழில்களில் ஒன்று ஆநிரை மேய்த்தலாகும்.

கொடுங்கோல் கோவலர் பின்னின் றுய்த்தர (15)

என்னும் அடியில் முல்லைநில மக்களைக் குறிப்பிட்டதுடன் அவர்தம் தொழிலையும் பதிவுசெய்துள்ளார் ஆசிரியர் நப்பூதனார். மேலும் முல்லைநில மக்களின் நீராதாரங்களில் ஒன்று கான்யாறு என்பதையும் தன் பாடலடிகளில் பதிவு செய்துள்ளதைக் காணலாம்.

கான்யாறு தழீஇய அகனொடும் புறவு (24)

இவ்வாறு முல்லைத்திணைக்குரிய கருப்பொருளான தெய்வம், மக்கள், மலர், விலங்கு, உணவு, தொழில் போன்றவை முல்லைப்பாட்டில் இடம்பெற்றுள்ளதைக் காணலாம்.

உரிப்பொருள்

முல்லைக்குரிய உரிப்பொருள் இருத்தலும் இருத்தல் நிமித்தமும் ஆகும். போர், தூது, கல்வி, பொருளீட்டல் போன்ற காரணங்களுக்காகப் பிரிந்து சென்ற தலைவனின் வருகைக்காக மனவேதனையுடன் காத்திருத்தல் எனும் பொருள்படுகின்றது. முல்லைப்பாட்டு முழுவதும் உரிப்பொருளை மையமிட்டே படைக்கப்பட்டுள்ளது. போருக்குச் சென்ற தலைவனை எண்ணி வருந்திக் கொண்டிருந்த தலைவியிடம் பெருமுதுப்பெண்டிர்

வருதல் தலைவர் வாய்வது நீநின்

பருவரல் எவ்வம் களை மாயோய் எனக்

காட்டவும்காட்டவும் காணாள் கலுழ் சிறந்து

பூப்போல் உண்கண் புலம்ப முத்து உறைப்ப (20-23)

என்று தேற்றுகின்றனர். தலைவன் விரைவில் திரும்பி வருவான் கவலைப்படாதே உனது துன்பத்தைக் களைவாயாக என்று ஆறுதலளித்தும் தேறுதலடையாதத் தலைவியின் மலர் போன்ற கண்களில் முத்துப் போன்று கண்ணீர் துளிகள் வெளிப்பட அவள் தலைவனின் வருகைக்காக ஆற்றியிருக்கின்றாள். பெருமுதுப்பெண்டிர் தலைவிக்கு ஆறுதல் கூறும் இப்பகுதி தலைவியின் உளக்கிடப்பை தெள்ளிதின் எடுத்தியம்புவதுடன் முல்லை நிலத்திற்குரிய உரிப்பொருளையும் எடுத்தியம்புகின்றது.

தோழிக்கூற்று வாயிலாக தலைவி ஆற்றியிருந்தது எடுத்துரைக்கப்பட்டுள்ளது. தலைவி தன் ஆற்றாமையை எண்ணி மயங்கி, நடுங்கி, கைகளிலிந்து நெகிழ்கின்ற வளைகளைத் திருத்தி துயருற்று வருந்தும் தன் நெஞ்சினைத்தானே தேற்றுகின்றாள்.

இன்றுயில் வதியுநற்காணாள் துயருழந்து

நெஞ்சாற்றுப் படுத்த நிறைதபு புலம்பொடு

நீடுநினைந்து தேற்றியும் ஓடுவளை திருத்தியும்

மையல் கொண்டும் ஓய்யென உயிர்த்தும்

ஏவுறு மஞ்சையின் நடுங்கி இசை நெகிழ்ந்து (80-84)

இதில் தலைவனது வரவை எதிர்நோக்கித்தன் நிலைமறந்து தனிமையில் வருந்துகின்ற தலைவி, தான் இப்படி வருந்துவது தலைவன் போருக்குச் செல்லும் போது அவனுக்குக் கொடுத்த வாக்கை மீறியது போலாகும் என்று நினைத்து தனக்குத் தானே ஆறுதல் கூறி ஆற்றியிருக்கின்றாள். முல்லைக்குரிய உரிப்பொருளான இருத்தலும் இருத்தல் நிமித்தமுமான உணர்வு வெளிப்பட்டிருப்பது முல்லைப்பாட்டின் தனிச்சிறப்பாகும்.

முடிவுரை

தொல்காப்பியம். நம்பியகப்பொருள் ஆகிய இலக்கண நூல்கள் சுட்டியுள்ள அகத்திணைச் சார்ந்த மரபுகளைப் பின்பற்றியே முல்லைப்பாட்டு அமைந்துள்ளது. அகத்திணை வகைமைகளான முதல், கரு, உரிப் பொருள் மட்டுமன்றி சுட்டி ஒருவர் பெயர் கூறாமல் அகத்திணை மரபுக்கு உட்பட்டு அமைந்துள்ளது. முல்லைத்திணைக் கோட்பாட்டுக்குரிய சிறந்த உதாரண நூலாக முல்லைப்பாட்டு விளங்குகின்றது.

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