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AWARENESS OF SOUTH AMERICAN TOMATO PINWORM (TUTA ABSOLUTA) AMONG TOMATO GROWING FARMERS OF NASHIK DISTRICT, MAHARASHTRA, INDIA.

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ABSTRACT

A field survey was conducted during 2023–24 to assess the awareness, perception and management practices of tomato farmers regarding tomato pinworm, *Tuta absoluta* (Meyrick), in Nashik district of Maharashtra. A structured questionnaire was administered to 140 tomato growers selected from seven major tomato-growing talukas, Nashik, Niphad, Dindori, Sinnar, Chandwad, Trimbakeshwar and Igatpuri (20 farmers per taluka). The study revealed that although a majority of farmers were aware of the pest's leaf-mining and fruit-boring nature, gaps existed in correct identification of life stages, economic threshold level and scientific management practices. Chemical control dominated pest management decisions, while adoption of integrated pest management (IPM) components such as pheromone traps, biological control and cultural practices was comparatively low. Different reasons behind the unknowingness about the insect pest *Tuta absoluta* are studied. The tomato crop is taken to a great extent in Nashik district and also the loss due to this pest is at its peak. The awareness about the life cycle of experimental pest and the managing tools was made among some of the farmers. With the management of experimental pest, the awareness of the pest is also necessary. The findings highlight the need for location-specific extension programmes and farmer-oriented training to promote sustainable management of *T. absoluta* in the district.

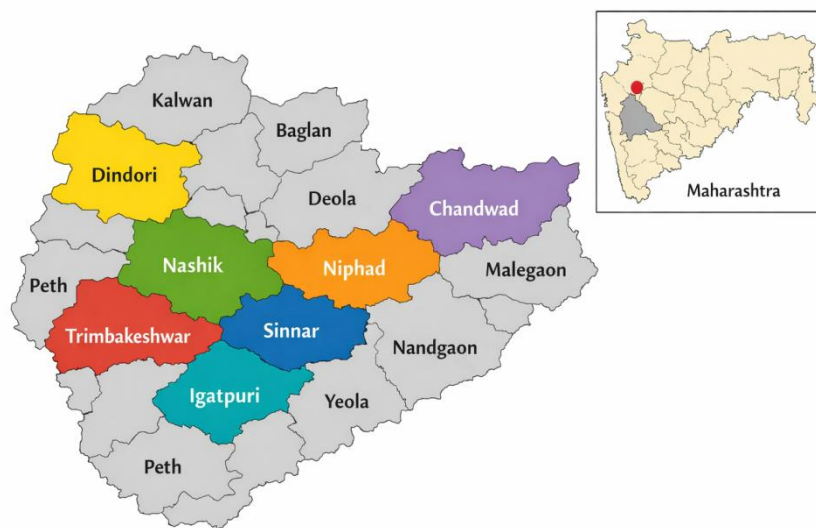
KEYWORDS

Tomato pinworm, survey, farmer knowledge, IPM, unknowingness, awareness, questionnaire

INTRODUCTION

Tomato is a remunerative vegetable crop which is very popular in the world for its taste, nutritive value and diversified use. Tomato (*Solanum lycopersicum* L.) is one of the most important vegetable crops cultivated in Maharashtra, with Nashik district emerging as a major production hub supplying both fresh

markets and processing industries. In recent years, tomato production has been severely constrained by the invasion and rapid spread of tomato pinworm, *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae). The larvae feeds voraciously upon tomato plants, producing large galleries in leaves, burrowing in stalks, and consuming apical buds and green and ripe fruits. It is capable of causing a yield loss of 100%.



NASHIK DISTRICT

Major tomato growing Talukas from Nashik District

Effective management of *T. absoluta* requires timely identification, knowledge of its biology and application of integrated pest management strategies by the farmers. However, farmers decisions are often influenced by their level of awareness, access to information and perception of control measures. Understanding the existing knowledge and practices of farmers is therefore needful for designing effective ways of management tools. The present investigation was undertaken to document taluka-wise knowledge, awareness, perception and management practices of tomato growing farmers regarding *T. absoluta* in Nashik district.

MATERIALS AND METHODS

Study area



The survey was conducted in Nashik district of Maharashtra, India. Seven major tomato-growing talukas, namely Nashik, Niphad, Dindori, Sinnar, Chandwad, Trimbakeshwar and Igatpuri, were selected for the study.

Sampling and sample size

A total of 140 tomato growers farmers were selected using purposive random sampling, comprising 20 farmers from each taluka.

Survey questionnaire and data collection

Data were collected using a pre-tested structured questionnaire covering aspects as following:

1. Awareness and identification of *T. absoluta*
2. Awareness about damage symptoms in tomato crops and crop stage affected.
3. Perception of severity and yield loss
4. Management practices adopted (chemical, biological, cultural and mechanical)

Personal interviews of tomato growing farmers were conducted during field visits in these seven Talukas.

Data analysis

Responses were compiled, tabulated and expressed as frequencies and percentages. Taluka-wise comparison of all the aspects of study was carried out.

RESULTS AND DISCUSSION

Awareness and identification of *Tuta absoluta*

A majority of farmers across all talukas were aware of *T. absoluta* as a serious pest of tomato (Table 1). Awareness was highest in Dindori (90%) and Nashik (85%), possibly due to higher tomato acreage and frequent pest outbreaks. However, correct identification of different life stages was relatively poor, indicating partial knowledge. Shows unknowingness of biology or the different life stages such as egg, larval stages, pupa and adult moth stage of the tomato pinworm.

Table 1. Taluka-wise awareness of tomato pinworm among tomato growers of Nashik district

Taluka	Farmers aware (%)	Farmers unaware (%)
Nashik	85	15

Niphad	80	20
Dindori	90	10
Sinnar	80	20
Chandwad	70	30
Trimbakeshwar	60	40
Igatpuri	40	60

Figures in parentheses indicate percentage of respondents (n = 20 per taluka).

Awareness about the damage symptoms of tomato crop and crop stage affected

Most respondents (farmers) correctly identified leaf mining as a common symptom, while fewer farmers associated fruit damage with *T. absoluta* infestation (Table 2). The vegetative and fruiting stages were perceived as most vulnerable. The farmers are totally unaware about the secondary infections like bacterial and fungal, after the tunneling of fruits by the tomato pinworm. Similar observations have been reported from other tomato-growing regions of India.

Perception of pest severity and yield loss

More than half of the farmers perceived *T. absoluta* as a high-severity pest causing significant yield losses (>30%). Farmers from Nashik and Dindori

Table 2. Knowledge of damage symptoms caused by *Tuta absoluta*

Damage symptom	Respondents (%)
Leaf mining	78
Stem tunneling	42
Fruit boring	55

Talukas which have been reported comparatively higher losses, those attributed to continuous tomato cultivation and favorable climatic conditions.

Management practices adopted by farmers

Chemical control was the most commonly adopted practice near about in all talukas (Table 3). Frequent use of broad-spectrum insecticides was reported. Adoption of pheromone traps and biological control agents was limited. It clearly indicates low awareness of IPM components among the farmers.

Table 3. Taluka-wise application of different management practices against *Tuta absoluta*

Taluka	Chemical control (%)	Pheromone traps (%)	Biological control (%)
--------	----------------------	---------------------	------------------------

Chandwad	80	30	10
Dindori	95	50	30
Igatpuri	85	20	2
Nashik	85	50	25
Niphad	80	40	5
Sinnar	75	30	5
Tryambakeshwar	80	25	2

The dominance of chemical control shows immediate effectiveness and easy availability, but it may increase the threats regarding resistance development in the *Tuta absoluta* and environmental safety issues in the future. Also the health issues among the farmers and society via the food chain and the water cycle also.

Chart -1

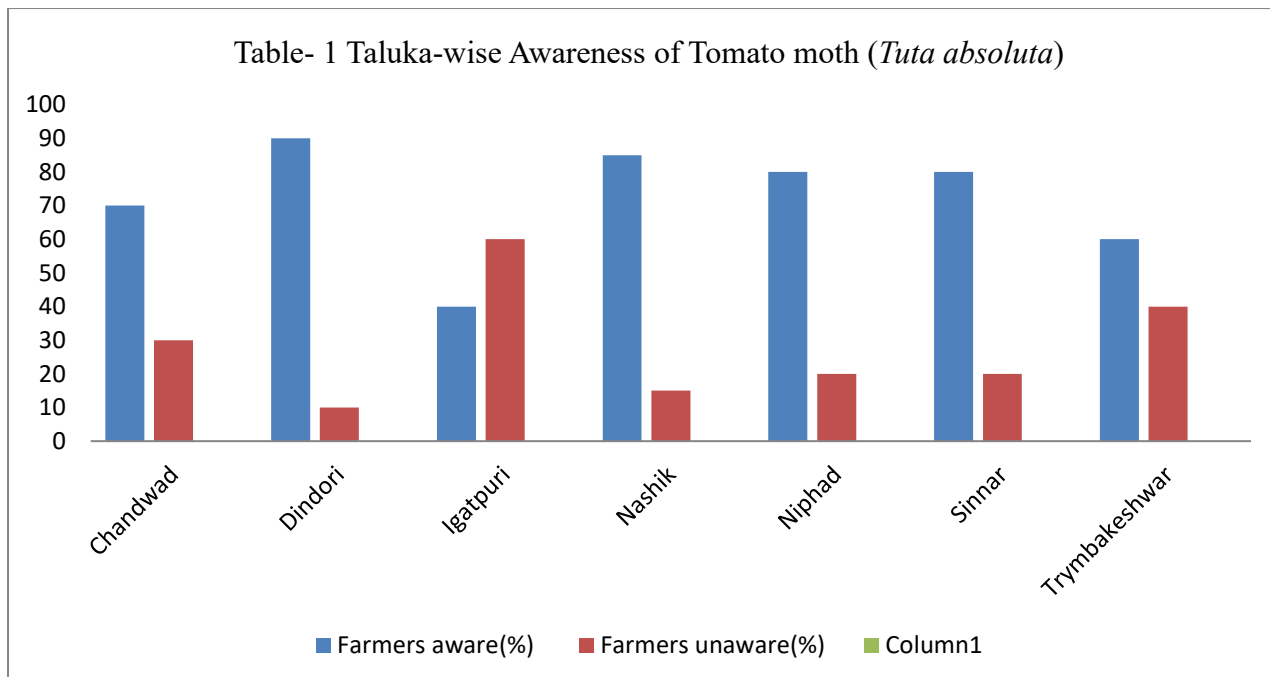


Chart -2

Table-2 Awareness about damage symptoms due to Tuta absoluta

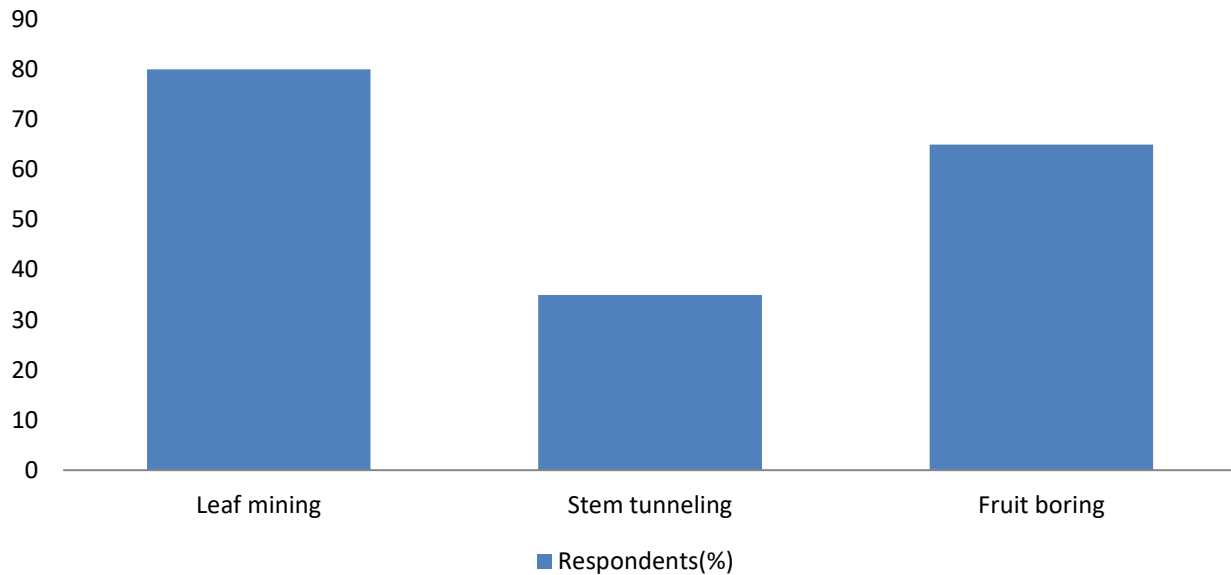
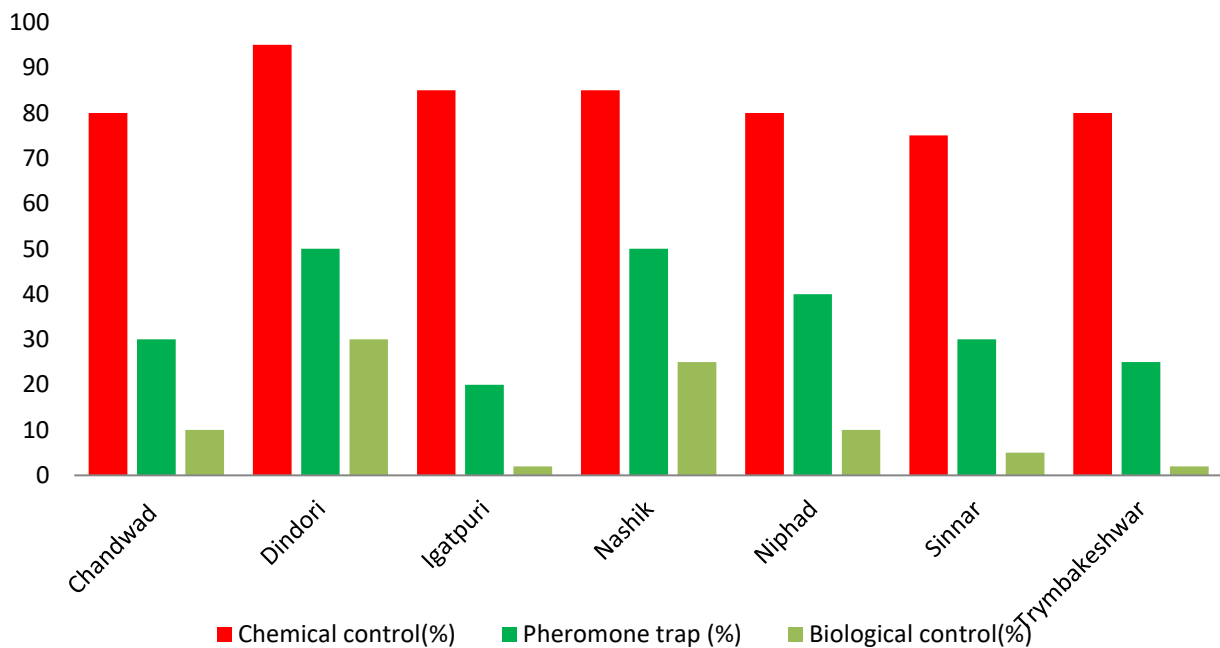


Chart -3

Table-3 Talukawise application of different management practices against Tuta absoluta



CONCLUSION



Tuta absoluta is one of the most harmful insect pests of several cultivated and non cultivated host plants, particularly tomato plant (*Solanum lycopersicum* L). Chemical insecticides are mainly used to manage The tomato leaf miner. However, their excessive use has led to several problems. Biological managment remains an eco-friendly alternative for management of this pest. It relies on using bacteria, entomopathogenic fungi, animals and plants. Plant extracts are easy to applicate and have low costs. Several species, plant parts and extracts forms are used. Biological effects of these extracts are due probably to their major components that affect vital physiological functions such as neurophysiology and and respiration of the pest. The survey clearly indicates that tomato growers in Nashik district possess moderate knowledge about *Tuta absoluta* and mostly rely on chemical control measures. Adoption of eco-friendly and integrated pest management practices remains limited due to various technical and economic problems. Specific targeted action plans, capacity-building programmes and promotion of IPM strategies are essential for sustainable management of *T. absoluta* in the region.

Acknowledgement-

Iam thankful to the tomato growing farmers of Nashik district for their cooperation and valuable information provided during the field visits. I express my profound sense of gratitude and sincere thanks to the funding agency ‘ Chhatrapati Shahu Maharaj Research Training and Human Development Institute ‘ (SARTHI) for providing me the financial assistance. I would like to express my deep and heartfelt gratitude to my family, research guide, HOD of Zoology , Principal of Maulana Azad College Chhatrapati Sambhajinagar.

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ETHNO – BOTANICAL KNOWLEDGE OF MEDICINAL PLANTS USED FOR LEUCORRHOEA IN RAHURI TEHSIL, AHILYANAGAR (MAHARASHTRA), INDIA

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ABSTRACT

The paper provides information on the use of plant crude drugs for Leucorrhoea diseases prevalent in tribal communities of Rahuri tehsil Ahmednagar district, Maharashtra. The local inhabitants in the region have inherited rich traditional knowledge of the use of many plant or plant parts for treatment of common diseases. They often have the information on how to use the plants and to take or to apply the medicines for different diseases, fodder and health care. Leucorrhoea is an abnormal excessive vaginal discharge commonly observed among women of reproductive age. Ethno-botanical surveys were conducted during 2024 and 2025 in villages. This paper explores its various types and causes, cultural perceptions, and ethno – botanical medicinal plant based treatments. In this paper 12 plant taxa belonging to 12 genera and 11 families. This research paper also gives some comparative studies with modern medicine, Pharmacogonosy used for Leucorrhoea with hygienic tips & risk factors in women. The tribal communities of the area depend on the herbal drug for their primary health care that is attributed partly to their socio-economic and cultural background.

KEYWORDS

Ethno – botanical knowledge, Medicinal Plants, Leucorrhoea, Rahuri Tehsil

INTRODUCTION

India is a treasure of biodiversity which hosts a large variety of plants and ranks 10th among plant rich countries of the world and 4th among the Asian countries. Medicinal plants are nature's gift to mankind and are rich heritage of India. According to WHO, 2008; the term "traditional medicine" is to be understood as the sum total of the knowledge, skills and practices based on theories, beliefs and experiences indigenous of different cultures that are used to maintain and improve health, as well as,



to prevent, diagnose and treat physical and mental illness. The WHO has a keen interest in documenting the use of medicinal plants by native peoples from different parts of the world (Buragohain, 2011). Folk knowledge of the people in a given community has developed over time and is based on experience, often tested over centuries of use, adopted to the local culture & environment and held by individuals or communities (Martin GJ, 1995). Leucorrhoea, commonly described as an excessive vaginal discharge, is a widespread gynecological concern affecting women of various age groups, particularly those in their reproductive years. While mild vaginal discharge can be physiological, excessive or abnormal discharge often indicates underlying infections, hormonal imbalances, or reproductive tract disorders. Leucorrhoea refers to the excessive or abnormal discharge from the female genital tract, typically white or slight yellowish. It may be benign or indicative of infection, inflammation, or systemic disorders. In India, where rural and tribal communities heavily rely on traditional healthcare knowledge, medicinal plants have played a significant role in managing female reproductive health issues, including Leucorrhoea. This paper explores the traditional wisdom associated with medicinal plants used for treating leucorrhoea, analyzing their phytochemical properties, therapeutic mechanisms, and relevance in contemporary healthcare systems. Traditional knowledge refers to the wisdom, practices, and skills developed by indigenous and local communities over generations. In healthcare, it includes herbal remedies, diagnostic methods, spiritual healing, and holistic approaches. Traditional medicine has historically addressed women's reproductive health, offering remedies for menstrual disorders, infertility, pregnancy-related care, and vaginal infections. Many herbal formulations for leucorrhoea still form a part of rural healthcare practices in India.

Types of Leucorrhoea

1. **Physiological Leucorrhoea** – is normal, healthy vaginal discharge that occurs due to hormonal fluctuations / activity, emotional stress or anxiety, puberty (estrogen production), active cervical and vaginal glands, ovulation, or pregnancy. It caused by Kapha predominance condition, It is not a disease and not indicate infection. It is the body's way of cleaning and lubricating vagina. It is white or clear and smell is mild or without smell. During physiological Leucorrhoea there is Painless.
2. **Pathological Leucorrhoea** – It's an Abnormal, excessive, foul smelling white / yellow / green vaginal discharge caused by microbial infections [bacterial (thin, grey – white), fungal (thick white, curdy discharge), or parasitic (frothy, yellow – green discharge)], poor genital hygiene,



sexually transmitted infections, or cervical erosions. It causes genital itching or irritation, backache, lower abdominal pain, dysuria, dyspareunia (painful intercourse), fever in severe infection (PID).

- Inflammatory Leucorrhoea:** Caused by [inflammation](#) or congestion of the vaginal [mucosa](#). In cases where it is yellowish or gives off an odor, a doctor should be consulted since it could be a sign of several disease processes, including an organic bacterial infection ([aerobic vaginitis](#)) or [STD](#). After [delivery](#), Leucorrhoea accompanied by backache and foul-smelling [lochia](#) ([post-partum](#) vaginal discharge, containing blood, mucus & [placental](#) tissue may suggest the failure of [involution](#) (the [uterus](#) returning to pre-pregnancy size) due to infection. A number of investigations such as [wet smear](#), [Gram stain](#), culture, [pap smear](#) and biopsy are suggested to diagnose the condition.

Study Area:

Rahuri tehsil is situated in the Ahilyanagar district, Maharashtra state, India. Rahuri Taluka of Ahilyanagar district has a **total population of 322,823** as per the Census 2011. Out of which 166,952 are males while 155,871 are females. In 2011, there were a total 64,707 families residing in Rahuri Taluka. The **Average Sex Ratio of Rahuri Taluka is 934**. As per Population Census 2011 data, **Schedule Caste (SC) constitutes 13.5%** while **Schedule Tribe (ST) where 10.5%** of total population in Rahuri Taluka of Maharashtra (Table 1).

(Table 1): Social Category wise sex ratio According to Census 2011.

Social Category	Total	Male	Female
Schedule Caste	43619	22320	21299
Schedule Tribe	34036	17177	16859

MATERIALS AND METHODS

Medicinal Plant Survey and Data Collection: Ethno – botanical exploration trips were carried out in primitive tribal people dominated villages during 2023 – 2025. The area under study was thoroughly covered and people were interrogated for information. After selecting the people, knowledge about their interests and skills in identification and utilization were obtained through informal interviews and discussion was made with the informants in their local language. A total of 30 informants (Mahadeo

Koli 5, Ramoshi 3 and Dhangar 7) between the age group 25 to 80 years were interviewed with questionnaires. Out of 30 informants, 25 are male and 05 are female. At the end of the each interview, specimens of plants mentioned for medicinal uses were collected and identified. Identification of species was made with the help of Floras (Flora of Maharashtra, Flora of Bombay Presidency, Flora of Ahmednagar district). The species and family names are mentioned according to APG III, systems of classification. The list of medicinal plants were depicted in a tabular form along with their botanical names followed by family, their local names in Marathi if any and the parts used for medicinal purpose.

Table 2: Ethno – botanical Medicinal Plants Used for Leucorrhoea

Sr. No.	Botanical Name, Family, Common Name	Habit& Plant Parts used	Disease & mode of usage	Pharmacogonosy
1	<i>Saraca asoca</i> (Roxb.) D. Willd. Fabaceae, Ashoka	Bark	Bark powder consumed with honey, two times a day.	Anti-diabetic, anti-inflammatory, and antimicrobial Uterine tonic.
2	<i>Azadirachta indica</i> A. Juss., Meliaceae, Neem	Leaves & Bark	Decoction of leaves or bark used for washing genital area.	Antifungal, antibacterial and detoxifying effects
3	<i>Asparagus recemosus</i> Willd., Asparagaceae, Shatavari	Roots	Prepare decoction of fresh root powder, administered twice a day.	Astringent, anti-septic, Tonic, Balance female hormones
4	<i>Curcuma longa</i> L., Zingiberaceae, Halad	Rhizome	Rhizome powder mixed with water and administered internally.	Antimicrobial, anti-inflammatory and healing effect
5	<i>Trigonella foenum-graecum</i> L., Fabaceae, Methi (Fenugreek)	Seeds	Boil 1 teaspoon seeds in a 1 glass of water for 5 -7 minutes, strain and drink warm once day.	Anti-oxidant, anti-inflammatory, Digestive and Reproductive
6	<i>Punica granatum</i> L., Lytharaceae, Dalimb (pomegranate).	Peel	Dry the outer peel of pomegranate fruit and make a fine powder. Mix 1tablespoon powder in 1 glass warm water and drink once daily.	Antioxidant, anti-inflammatory, antimicrobial anti-diabetic, cardioprotective and anti-cancer
7	<i>Abelmoschus esculentus</i> (L.) Moench., Malvaceae, Bhendi (Lady's finger)	Fruit	Cut 4-5 pieces of lady finger, boil in 2 cups of water until it becomes half, drink once daily.	Antidiabetic, antioxidant, anticancer, cardioprotective, anti-inflammatory

8	<i>Musa paradisiaca</i> L., Musaceae, keli (Banana)	Fruit	Eat 1 ripe banana with 1 teaspoon amla powder daily.	Anti-diabetic, anti- oxidant, anti-ulcer, anti-microbial and anti-diarrhoeal
9	<i>Ocimum tenuiflorum</i> L., Lamiaceae, Tulsi	Leaves	Take 1 teaspoon tulsi juice or paste, mix with 1 teaspoon honey. Take twice a day.	Analgesic, anti- asthmatic, anti- bacterial, anti-cancer, anti-helminthic
10	<i>Oryza saiva</i> L., Poaceae, Tandul (Rice)	Seeds	Cook rice in excess water, stain and drink the leftover rice water once daily.	Gastrointestinal, dermatological, cardiovascular, anti- inflammatory, anti- oxidant
11	<i>Piper betel</i> L., Piperaceae, Nagin pan (Betel)	Leaves	Chew 1 fresh betel leaf daily or make a mild wash by boiling betel leaves in water and using externally when warm.	Gastroprotective, anti-microbial, anti- fungal, aphrodisiac, anti-platelet
12	<i>Ficus carica</i> L., Moraceae, Anjeer	Fruit	Soak 2-3 anjeer in water overnight, eat them in the morning.	Anti-carcinogenic, anti-oxidant, anti- fungal, Hypo- cholesterolemic, anti- anxiety, digestive

RESULTS AND DISCUSSION

The present paper gives detailed information on 12 plant species, from different 11 families were made which are used traditionally against Leucorrhoea disorders. The present survey shows that the practice of ethno-botany is still a matter of cultural heritage of the area. People are making maximum use of the plant species for meeting their day to day household remedies. Traditional healers use their five senses to diagnose the diseases, which are remarkable because they live in remote areas and lack of the modern scientific equipment for diagnosis and treatment; however, they treat diseases using medicinal plants. Traditional knowledge of medicinal plants offers valuable insights into managing Leucorrhoea naturally. Many plants used for generations show scientific backing through phytochemical studies. However, standardization, dosage determination, and clinical trials are essential to ensure safety and efficacy. Preserving indigenous knowledge systems is crucial, particularly in rural communities where plant-based medicine remains the first line of treatment. The medicinal plants covered in the present study warrant extensive research work to exploit their full potential in the future.

Causes and Risk Factors for Leucorrhoea: There are some causes and risk factors enlisted below which are important in this study. Out of them poor personal health & hygiene, Prolonged use of strong antibiotics, stress and nutritional deficiencies, poor knowledge of cleanliness, clothing & wearing patterns etc. These will finally leads to Hormonal imbalance, Vaginal or cervical infections, Pelvic inflammatory disease & Sexually transmitted diseases (STD)

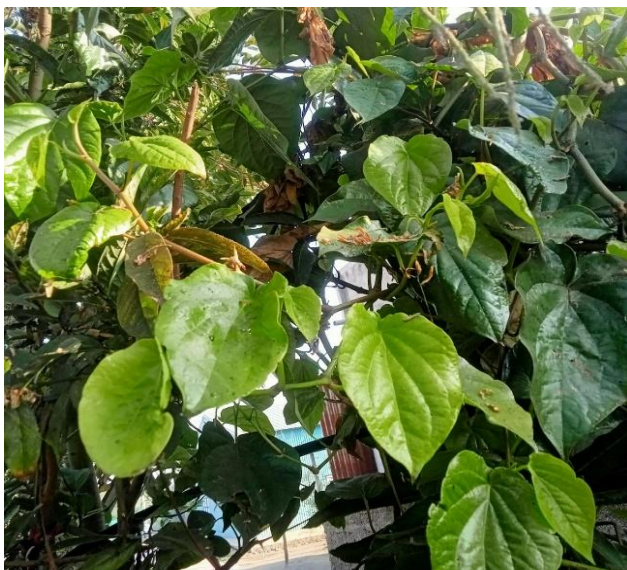
Ficus carica Linn.



Punica granatum



Piper betle

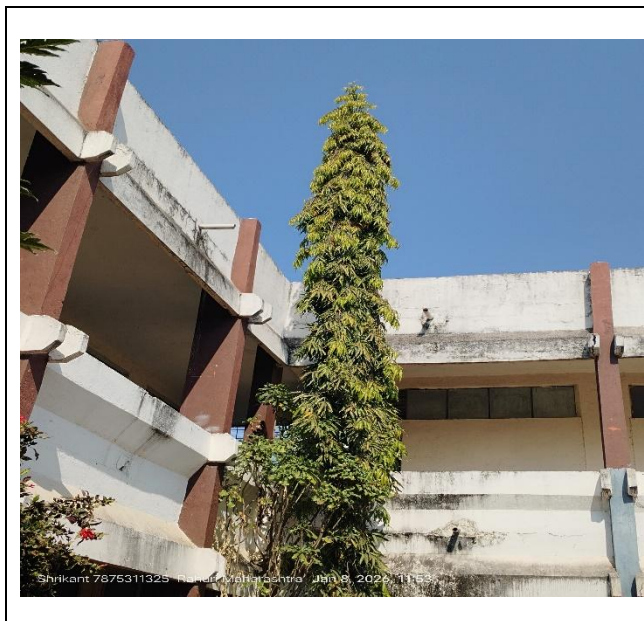


Ocimum tenuiflorum L. Tulsi



Saraca asoca (Roxb.) Ashoka

Azadirachta indica Meliaceae, Neem



Phytochemical Properties and Mechanisms of Action: Medicinal plants with their therapeutic potential to diverse phytochemicals are flavonoids, tannins, alkaloids, Saponins and glycosides etc. **Flavonoids** Provide antioxidant and anti-inflammatory benefits. **Tannins** offer astringent action and reduces excessive discharge. **Alkaloids** Exhibit antimicrobial activity which prevents smelling and microbial infections. **Saponins** – Helps to regulate hormones and improve uterine health. While, **Glycosides** Support immune function and tissue healing. These compounds work through multiple mechanisms such as inhibiting pathogen growth, reducing inflammation, restoring vaginal pH balance, and strengthening reproductive tissues. Leucorrhoea, though common, can significantly affect women's quality of life. Traditional medicinal plants provide effective and culturally accepted solutions for managing this condition. Integrating traditional knowledge with modern scientific research can enhance women's healthcare while preserving valuable ethno-medical heritage. This study reveals the traditional uses of some medicinal plants for prohibition of abnormal Leucorrhoea among the women. **Traditional medicine** emphasizes holistic care using readily available herbs, focusing on root causes, nutritional balance, and long-term wellbeing while **Modern medicine** uses antifungals, antibiotics, hormonal treatments, and probiotics for rapid relief. While modern treatments are effective for acute infections, traditional remedies offer long-term prevention with minimal side effects. Integrating both systems can provide comprehensive healthcare.



Hygienic Tips & Suggestions:

1. Wear cotton underwear only.
2. Keep area clean and dry.
3. Avoid tight jeans.
4. Change underwear twice a day if discharge is heavy.
5. Do not use harsh soaps, Dettol or perfumed washes.

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EFFECT OF COPPER NANO PARTICLE AGAINST LEAF SPOT OF CAULIFLOWER

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ABSTRACT

Alternaria leaf spot caused by *Alternaria brassicicola* (Schwein) Wiltshire is one of the most destructive disease of the cauliflower (*Brassica oleracea* var. *botrytis*), causing high losses. The present investigations were taken for management of *Alternaria* leaf spot of cauliflower with CuNP. Result revealed that all the treatments significantly reduced the leaf spot disease incidence over control. Experiment was taken for the evaluation of efficacy of CuNP against *A. brassicicola* in *in vitro*. CuNP @0.5% and 1% were evaluated in *In vitro* conditions against *A. brassicicola* using poisoned food technique. CuNP exhibited maximum inhibition in mycelial growth. Nanoparticles can play a major role in coming days for the management of plant diseases at large scale and protect the farmers from indebtedness by decreasing the cost of production.

KEYWORDS

Alternaria, CuNP, Cauliflower, disease

INTRODUCTION

Cauliflower or *Brassica oleracea*, is a member of the Brassicaceae family. It is a winter vegetable that is grown all over the world. [1]. Its floral shape is reflected in the name, which is derived from the Latin words *caulis* (cabbage) and *floris* (flower). Through natural mutation and selection, it developed from wild cabbage. [2]. Cauliflower is cultivated in many countries like China, India, Italy, Mexico, France, Poland, U.S.A, Pakistan, Germany, Egypt etc. India is the world's second-largest producer of cauliflower after China. During 2021-22, national production reached 89.41 lakh metric tonnes [3]. In Chhattisgarh, the crop cultivated over 24,250 hectares, with a production of 483,565 metric tonnes and an average productivity of 19.94 t/ha [4]. Protein, vitamins B1, B2, B5, B6, and C, omega-3 fatty acids, folate, phosphorus, manganese, and dietary fiber are all abundant in cauliflower. Cauliflower has been



found to contain a number of phytochemicals, including isothiocyanates, glucosinolates, and indoles, which detoxify carcinogens and inhibit the enzymes that cause tumors and malignancies. [5].

Cauliflower [*Brassica oleracea* (L.) var. *botrytis*], *Alternaria brassicicola* (Schwein) Wiltshire is the dominant pathogen. All growth phases are impacted by the leaf spot disease, which goes by several names throughout the world, including curd blight, brown rot, and black spot. There have been reports of this disease in several nations, including India. [6]. It has reported 20-80 per cent loss in yield and 59 per cent loss in seed production. Globally, the loss due to this disease is 30-47 percent. In India, about 30 percent losses in terms of seed and yield was reported [7].

Nanoparticle research has attracted more attention because of their special qualities—such as electrical conductivity, toughness, and ductility; enhanced hardness and strength of metals and alloys; and luminous efficiency of semiconductor. [8]. Metal oxides such as Copper Oxides (CuO) have attracted attention mostly because of antimicrobial [9, 10] and biocide properties which can be used in many biomedical applications. Apart from the earlier mentioned applications Copper-based nanoparticles also showed advantageous usage in cancer detection [11], as nanofluids in heat transfer systems [12], and as catalyst [13], photocatalysts [14]. In general, copper-based nanoparticles are less costly than other extensively researched nanoparticles like gold and silver. Plant extract-based nanoparticle synthesis has many benefits, including readily available resources, a safer alternative, an eco-friendly approach, a straightforward technology, and low cost. [15].

Due to the limitation in use of fungicides as it causes the environmental pollution and health hazards, use of nanoparticles may be safer and least expensive. The present investigations were carried out to generate information on potentiality of some promising nanoparticles under *in vitro* as well as *in vivo* conditions against *Alternaria* leaf spot of cauliflower and its causal agent.

MATERIALS AND METHODS

Collection of the diseased samples.

Leaves of cauliflower with dark brown spots having characteristic concentric circumferences, often with a yellowish chlorotic halo were collected from farmer's field of nearby Loni and brought to the laboratory for isolation and further studies.



Isolation

For isolation of pathogen, small pieces of the leaves were cut from the diseased portion and surface sterilized with 1% sodium hypochlorite solution for one minute followed by three consecutive washings with sterilized distilled water. The surface sterilized pieces were transferred to Petri plates containing Potato Dextrose Agar (PDA) and incubated at 25+1°C in BOD incubator.

Preparation of Plant Extracts

The extract was used to produce Copper oxide nanoparticles. 20g fine grounded powders of *Coriandrum Sativum* was weighed, separately added to 200 ml of double distilled water, and heated at around 80°C for 30 minutes in a water bath. The mixture was filtered separately. The filtrate was stored for further use in a refrigerator (in a cold condition).

Synthesis of Copper Oxide Nanoparticles using *Coriandrum Sativum* Extract

In 200 ml of *Coriandrum Sativum* extract were taken separately. 50 ml of 1M Copper Sulphate ($\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$) solution was added drop wise to extract while stirring on the magnetic stirrer. During the addition of the Copper Sulphate solution, the gradual change in the color of the solution was observed from brown to dark green visually indicating the formation of nanoparticles. The solutions were stirred for about 1 hour for completion of the reduction reaction and were kept aside for 24 hours. These solutions were then centrifuged at 4000 rpm with washings of double distilled water. The solid precipitate obtained was collected and oven dried for 2 hours at 50°C to 60°C. The dried powder was obtained from extracts and used for further analysis.

In Vitro Antifungal Activity Assay

The antifungal activity of Cu-NPs against *Alternaria brassicicola* was evaluated using the poisoned food method [16]. Briefly, PDA was mixed with different amounts of Cu-NPs to obtain the following final concentrations 0.5% and 1% and non-amended media were used as control. Spore suspensions (1×10^6 CFU/mL) were inoculated at the center of each PDA plate and incubated in darkness at 28 °C for six days. All treatments were carried out in triplicate. Colony diameters were measured three and six days after inoculation (dai). The percentage of growth inhibition was calculated by measuring the average area of the fungal colonies in the treatments and compared to the negative control.

RESULTS AND DISCUSSION

Isolation and identification-

On potato dextrose agar medium, the pathogen was successfully isolated from diseased tissue. The inoculation plates were incubated in the BOD incubator for 5 to 7 days at a temperature of 25 to 20°C. After seven days of incubation, the fungus generated greenish-gray to black-colored, fluffy, lanose to loose cottony growth on potato dextrose agar medium. The pure culture of *Alternaria brassicicola* obtained by single spore isolation method was used for pathogenicity test. The test was carried out by spore suspension spray inoculation on the foliage of 35 days old. The symptoms appeared on inoculated leaves as brown, circular or oval necrotic spots with concentric rings and surrounded by yellow after twenty days after inoculation. The fungus was re-isolated and purified and compared for similarity to that of original culture.

Nanoparticle synthesis by UV- Visible Spectroscopy Analysis [17]

Nanoparticles in the reaction mixture were excited by light absorption at different wavelengths due to surface plasmon resonance (SPR) to give respective peaks in the wavelength range from 200 nm to 600 nm to determine the absorption. The synthesized nanoparticles from Coriandrum Sativum plant extracts showed broad peaks at 327 nm, which corresponds to Copper Oxide. Thus, it was confirmed that the Copper Oxide nanoparticles were formed using Coriandrum Sativum plant extracts.

Antifungal Activity-

The radial growth of the fungal mycelium was recorded at 7 days after inoculation. Zone of growth of fungus of control plate is 4.2 cm whereas zone of growth of CuNp at 0.5% and 1% is 1.9 and 1.2 cm respectively.

CONCLUSION

The presented work proves that using Cu-NPs could be considered as a highly efficient alternative with better antifungal properties. The study revealed that the disease can easily be identified by its characteristic's symptoms, and observing the asexual reproductive structures of the causal pathogen in aqueous medium that will help the farmers for selecting effective treatment against the disease easily. This method has merits over other reported methods are easily available starting materials, inexpensive process, easy to carry out in any college level laboratory, reaction condition are simple, avoid use of expensive, hazardous and toxic reagent and pollution free.



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FORMULATION AND EVALUATION OF SUSTAINED RELEASE TABLET USING NATURAL POLYMER

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ABSTRACT

Natural polymers have gained significant attention in pharmaceutical research due to their biocompatibility, biodegradability, low cost, and ability to control drug release. These materials, derived from plant, microbial, and animal sources, serve as retardant and controlled-release agents in oral dosage forms. Polymers such as carrageenan, pectin, and glucomannan exhibit excellent swelling, gel-forming, and diffusion-controlling properties that enable sustained drug delivery. Carrageenan, a sulfated polysaccharide from *Chondrus crispus*, exists in κ , ι , and λ forms, each differing in sulfate content and gelling capacity. It has been used in various matrix systems to modulate drug release up to 24 hours. Similarly, pectin, composed of α -(1,4)-linked D-galacturonate units, forms gels depending on its degree of methylation and pH, influencing solubility and drug release kinetics. Sustained release tablets aim to maintain steady plasma drug levels, reduce dosing frequency, minimize side effects, and improve patient compliance through mechanisms such as diffusion, erosion, and swelling. Natural polymers like cellulose, agar, and xanthan gum are widely used as binders, gelling agents, and stabilizers in these formulations. Their renewable nature and ease of modification make them ideal for designing advanced drug delivery systems. Future developments in polymeric drug delivery focus on responsive and biomimetic systems that allow targeted, controlled, and efficient release, particularly in cancer therapy. The integration of natural and synthetic polymers offers promising prospects for developing innovative, site-specific, and patient-friendly pharmaceutical formulations that enhance therapeutic efficacy while minimizing adverse effects.

KEYWORDS

Polymers, delivery, Release, Specific, Effect, Tablet



INTRODUCTION

Polymers have been used in pharmaceutical applications, particularly as retardant release for oral controlled release formulations, because of their many benefits, including being inert, biocompatible, inexpensive, readily available in nature, convenient, and easy to manufacture. Depending on the polymers, they can also provide a desired drug release profile. Natural polymers and other hydrophilic polymers show promise as retardants and controlled release agents because they prolong drug release and trap the drug in a matrix to control its release by controlling swelling and diffusion through the polymer. This makes them especially well-suited for controlled release platforms. Controlled release formulations based on natural and hydrophilic polymer matrix have been thoroughly researched lately. The properties of natural polymers are crucial in determining the process in a number of situations. and the drug to polymer ratio, solubility, viscosity, and swelling capacity all affect the kinetics of drug release. Chondrus crispus (Rhodophyceae) is the source of carrageenan, a high molecular weight sulphated polysaccharide. Based on differences in the degree of sulfation, the carrageenan is separated into three groups: kappa (κ), iota (ι), and lambda (λ) with di, mono, and three sulfate, respectively. Ester sulfate is the basis for carrageenan's properties; a high ester sulfate content results in reduced solubility and gelation strength.

The ionic strength of carrageenans determines their gelling capabilities; κ -carrageenan produces stronger gel presences of K^+ , γ -carrageenan produces stronger gel presences of Ca^{2+} , and λ -carrageenan has no gelling feature. High ratios of either γ or κ carrageenan blended with λ -carrageenan have been investigated, given that zero order release and burst release happened in blend γ/κ -Tolterodine is used as a drug model for carrageenan, a medication that is somewhat soluble in water. A blend of carrageenan and hydroxyl-propyl methylcellulose has been used in gastro-retentive drug delivery systems to improve their floating capability and delay the drug for up to five hours. A combination of carrageenan and polyvinyl alcohol has been studied to reduce the burst release in carrageenan hydrogel 15. Other modifications using polyacrylamide and carboxymethyl of carrageenan have been prepared to improve the ability for drug delivery. Using doxazosin melsate as a drug model, carrageenan (δ , κ , and λ) extended the drug release up to 24 hours; κ -carrageenan demonstrated a burst release effect.



Pectin is a polysaccharide and oligosaccharide made up of α -(1,4)-linked D-galacturonate units with a methyl ester group on the C-6. Pectin's degree of methylation affects its solubility and capacity to form networks. and the features and mechanism of gelation. Low methoxy pectin is more hydrophilic and soluble than high methoxy pectin in pH 7.4 buffer, while high methoxy pectin is poorly soluble and forms gel at pH around 3. The degree of esterification and molecular size of the pectin determine its gelling property. According to reports, pectin forms gel at pH 1-3, and its gelation properties decrease as pH rises. When natural polymers come into contact with a medium, they instantly hydrate, expand, and form a viscous gelatinous surface barrier that controls drug release and permits medium penetration into the matrix system's core. Drug and polymer solubility, polymer hydration/erosion rate, and other factors determine the drug release kinetics and mechanism from these matrices. particle size and shape, drug-to-polymer ratio, and the capacity for swelling and gelling. Different drug release patterns, kinetics, and mechanisms result from variations in drug release kinetics. Therefore, it is necessary to clarify and study the drug release properties, kinetics, and mechanism from natural polymers like carrageenan, pectin, and glucomannan as a single system using difference dispersion drug to polymer ratio. To the best of our knowledge, no assessment of drug release kinetics, models, and properties utilizing natural polymers like carrageenan, pectin, and glucomannan has been carried out thus far. Therefore, the purpose of this study was to examine and assess the drug release properties, models, and kinetics of sustained release tablet formulations based on natural polymers, such as carrageenan, pectin, and glucomannan[1,2]

SUSTAINED RELEASE TABLET

Extended release By preserving a steady-state concentration of the medication in the systemic circulation, dosage forms are especially made to extend the duration of therapeutic activity, decrease the frequency of administration, lessen adverse effects, and ultimately increase patient compliance. In order to ensure therapeutic efficacy with less variations in plasma drug concentration, these dosage forms seek to administer the medication at a regulated pace over a longer period of time. Diffusion, erosion, osmotic pressure, and swelling-controlled release are the mechanisms involved in sustained release; each one contributes in a unique way to regulate the drug's release from the dosage form. Because of its ease of use, versatility in dosage form formulation, and improved patient acceptability, the oral route of medication administration is the most popular. However, it is crucial. should take into



account elements that can affect the behavior of the medication and the effectiveness of the dosage form throughout its transit, such as the enzyme system, gastrointestinal motility, and the fluctuating pH levels throughout the gastrointestinal tract. To provide a steady and gradual release of the medication into the gastrointestinal environment, the majority of oral sustained release devices rely on dissolution, diffusion, or a combination of these processes. A zero-order release mechanism, in which the drug is supplied at a constant rate and produces a stable blood concentration–time profile akin to that of continuous intravenous infusion, is the ideal sustained release delivery method, both theoretically and desirably. By reducing the possibility of dose-related adverse effects and increasing overall treat efficacy, such a system offers the best possible therapeutic benefits[3].

CONTROLLED RELEASE:-

A variety of prolonged action formulations that offer continuous release of their active components at a predetermined rate and for a predetermined amount of time are included in controlled release dosage forms. Although these devices have lately been created for parenteral administration, ocular insertion, and transdermal application, the bulk of these formulations are intended for oral delivery. The primary goal of this system's creation is to provide a longer duration of effect, which will increase patient compliance[4].

ADVANTAGES OF SUSTAINED RELEASE TABLETS:-

- 1) Increased Effectiveness of Treatment Prolonged Drug Release: Sustained-release tablets improve the pharmacological response by keeping therapeutic drug levels in the bloodstream for a longer amount of time.
- 2.) Enhanced Patient Compliance Decreased Dosing Frequency: Patients take these tablets once a day or less, which improves adherence to the treatment plan, particularly for long-term diseases.
- 3) Mitigate the toxicity by decelerating the absorption of the drug.
- 4) It keeps a therapeutic concentration for an extended duration.
- 5) Less frequent intakes.
- 4) Mitigate adverse effects.



6) Consistent drug release throughout the duration[5,6].

DISADVANTAGES OF SUSTAINED RELEASE TABLETS:-

(1) Very costly

(2) Bioavailability is often inadequate

(3) Requirement for additional patient counseling and education.

(4) Überdosierung bei der Applikation

(5) Häufig mangelhafte Korrelation zwischen in vivo und in vitro. Mitigate the toxicity by decelerating the absorption of the drug.

6) It keeps a therapeutic concentration for an extended duration.

7) Less frequent intakes.

8) Mitigate adverse effects.

9) Consistent drug release throughout the duration[7,8].

POLYMERS:-

Es gibt deep historical ties between the domain of polymer science and nature. It is worth mentioning that polymers are, in fact, essential for all living organisms. As an illustration, cellulose, recognized as the most prevalent organic substance on Earth, serves as a primary structural component for plants. Foods such as potatoes and cereal grains contain a high amount of starch. Various bacteria, including *Cupriavidus necator* and *Alcaligenes latus*, naturally produce polyhydroxyalkanoates (PHAs). Natural rubber is obtained from *Hevea brasiliensis* trees. Chitin makes up the exoskeletons of insects and shellfish. The mulberry silkworms produce silk. Proteins, crucial for all life forms including humans, are involved in essentially all processes in every living cell, as well as nucleic acids that hold the genetic information for all Earth's life forms, are located in the cell nuclei. Studying the structures, properties, and biological functions of natural polymers is of significant scientific interest, as it can help reveal nature's secrets and discover new applications, including in the biomedical and pharmaceutical



fields. From the outset of polymer research, attention has been directed toward designing, synthesizing, and utilizing new polymers, as well as natural polymers, for nature[9].

NATURAL POLYMERS:-

Proteins, which are composed of various amino acids and exhibit monodispersity, can have different physical and biochemical properties due to the attachment of various moieties to their amino acid side chains. Proteins can have limitations, including immunogenicity and variations from one batch to another due to the purification process. Moreover, protein materials are typically obtained from animals, which adds complexity to their translation into a clinical context [Research has been conducted on proteins like collagen, elastin, silk fibroin, and gelatin to evaluate their potential as scaffolds for tissue applications. Protein-based materials like these are beneficial for sutures, drug delivery vehicles, and more. Materials based on proteins, as well as biomaterials overall, must offer adjustable degradability to regulate the sequestration and delivery of particular bioactive elements that enhance and direct healing and regeneration for an extended duration. Below, we will discuss collagen, gelatin, and silk fibroin along with the incorporation of bioactive glasses[10].

SOURCE OF NATURAL POLYMERS:-

Due to its physicochemical properties, natural polymer has undoubtedly garnered interest in the drug delivery system. The polymers sourced from plants (such as pectin, guar gum, and mannan), microbes (like dextran and xanthan gum), and animals (including chitosan or chondroitin) are found abundantly in the atmosphere and can be easily reproduced using recombinant DNA technology. The polymers of monosaccharides possess numerous advantageous characteristics, including high stability, non-toxicity, hydrophilicity, biodegradability, gel-forming capability, and ease of chemical modification. The structural compositions of plant polysaccharides vary widely, linked not only to different plant species but also to the specific parts of plants from which they are derived, including leaves, seeds, roots, and tubers. Two specific structural characteristics can elucidate the complexity and diversity of polysaccharides: First, monosaccharides can be linked in α or β configuration; second, because of the branched side chains. Amino acid-based natural polymers are relatively uniform in size, with no variation present. Polymers of this kind are described as homogeneous or monodisperse. Generally, the natural polymers are produced through condensation polymerization techniques. Natural polymers

are usually easily biodegradable and do not have adverse effects on the environment or humans. According to the sources, natural polymers are classified into three main categories, as shown in table[11].

TABLE:-

Natural Polymer	Source	Key Properties	Mechanism of Release Control
Guar Gum	<i>Cyamopsis tetragonolobus</i>	Hydrophilic, forms viscous gels	Swelling and diffusion control
Xanthan Gum	<i>Xanthomonas campestris</i> (bacterial origin)	High viscosity, stable at various pH	Matrix formation and diffusion
Okra Gum	<i>Abelmoschus esculentus</i>	Good binding and swelling properties	Swelling and gel barrier formation
Pectin	Citrus peels, apple pomace	Gel-forming in acidic pH	Ion-exchange and diffusion
Sodium Alginate	Brown algae	Forms hydrogels with Ca ²⁺ ions	Diffusion and erosion control
Chitosan	Chitin (crustacean shells)	Mucoadhesive, biocompatible	pH-dependent release

.CLASSIFICATION OF POLYMERS:-

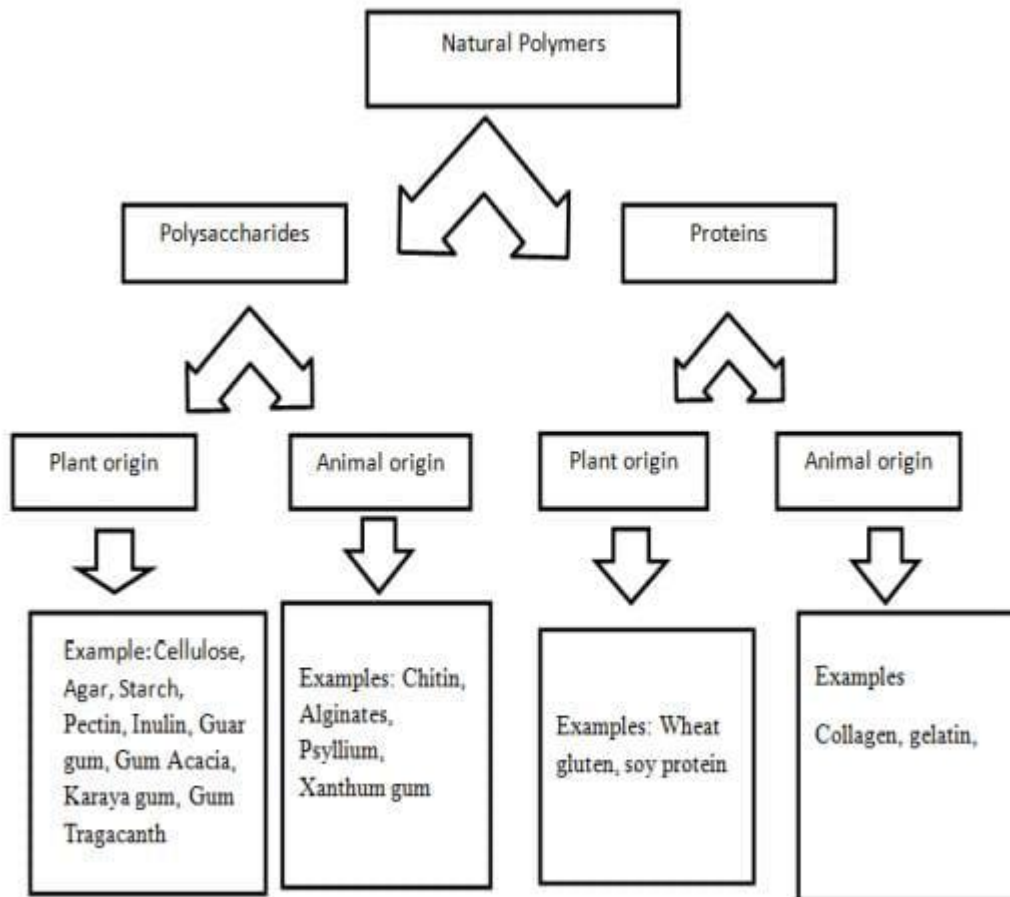


Fig 2 :- classification of polysaccharide

CLASS 1 :-POLYSACCHARIDE

POLYSACCHARIDES FROM PLANT ORIGIN

a) CELLULOSE:-

*Composition:- It is an organic polysaccharide made up of a linear sequence of several hundred to more than ten thousand D-glucose units linked by β (1 \rightarrow 4) bonds, with the formula $(C_6H_{10}O_5)_n$. The primary components of the plant cell wall are cellulose, hemicelluloses, and pectin.

*Applications :- In the pharmaceutical sector, microcrystalline cellulose serves primarily as a diluent and binder in tablets, applicable to both granulation and direct compression methods.

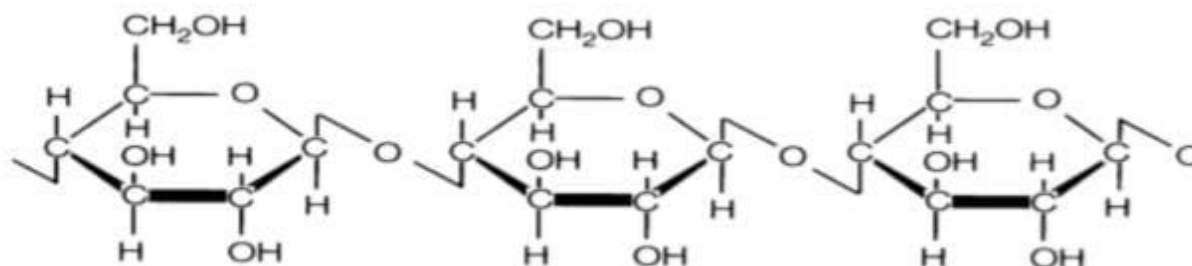


Fig 3:- Cellulose

b) AGAR

*Composition: Agar setzt sich aus einer Kombination von Agarose und Agaropektin zusammen. Agarose, a linear polymer, consists of repeating units of the monomer agarobiose. Agarobiose, on the other hand, is a disaccharide composed of D-galactose and 3,6-anhydro-L-galactopyranose. Agaropectin consists of a variety of smaller acidic molecules

*Application : Agar serves various roles, including as a suspending agent, emulsifying agent, and gelling agent in products such as suppositories, surgical lubricants, tablet disintegrants, bacterial culture media, and laxatives. Additionally, it serves in the making of jellies and sweets, as well as in tissue culture research and microbiological studies.

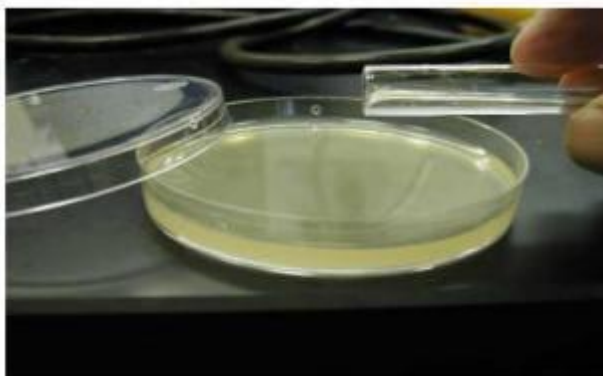


Fig 4:- Agar

C) STARCH

*Composition

Starch, also known as amyllum, is a carbohydrate made up of numerous glucose units linked together through glycosidic bonds. It is composed of two polymers: amylose, which is a non-branching helical polymer made up of α -1,4 linked D-glucose monomers, and amylopectin, a highly branched polymer containing both α -1,4 and α -1,6 linked D-glucose monomers.

* Applications Thermoplastic starch serves various purposes, including in packaging, containers, mulch films, textile sizing agents, and adhesives.



Fig 5:-starch

D) GUAR GUM

* Composition:- Guar gum is a natural polysaccharide made up of the sugars galactose and mannose from a chemical perspective. It is a galactomannan, a linear polysaccharide made up of β -D-mannose monomers linked by (1 \rightarrow 4)-diequatorial connections, with some connected to single α -D-galactose sidechains. The backbone of guar gum consists of β -1,4-linked D-mannopyranoses, with an α -D-galactose linked 1 \rightarrow 6 to every alternate mannose on average.

*Application :-Various modified forms of guar gum are utilized in drug delivery systems.The formulation of the transdermal therapeutic system utilizes carboxymethyl guar film. Guar gum is especially effective

for colon delivery as it can be broken down by certain enzymes found in this area of the gastrointestinal tract[12].



Fig 6:- gaur gum

II. POLYSACCHARIDES FROM ANIMAL ORIGIN

a) Xanthan gum

*Composition:- Xanthan consists of long-chain polysaccharides that have numerous trisaccharide side chains. The side chains consist of two mannose units and one glucuronic acid unit.

*Application :-Xanthan gum serves as a suspending and stabilizing agent in a variety of products, including oral and topical pharmaceuticals, cosmetics, and food items. Additionally, it serves as a thickening and emulsifying agent. Xanthan gum has been utilized in the formulation of sustained-release matrix tablets. An ophthalmic liquid dosage form has been developed that includes xanthan gum. This ingredient interacts with mucin, aiding in the dosage form's extended retention in the precorneal area. Recent studies have shown that xanthan gum can serve as an excipient in spray-drying and freeze-drying processes, leading to improved results.

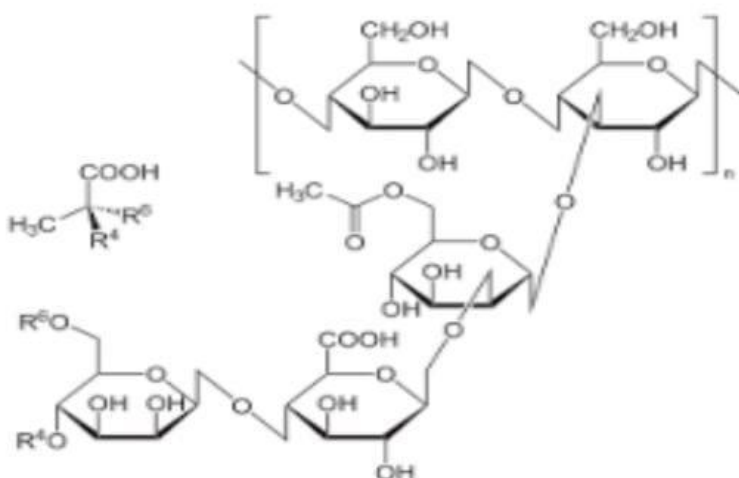


Fig 7:- xanthan gum

b) ALGINATE

*Composition:- These polymers consist of two different monomers in varying proportions, namely D-mannuronic acid and L-glucuronic acid, linked by 1,4-glucosidic bonds. They can exist as blocks of only D-mannuronic acid and L-glucuronic acids in homopolymers or as alternating sequences of the two in heteropolymeric blocks.

*Application:- A variety of oral and topical pharmaceutical formulations utilize sodium alginate. Sodium alginate serves as a binder and disintegrant in tablet formulations, while in capsule formulations, it has been utilized as a diluent. Sodium alginate has also been employed in creating sustained-release oral formulations. In topical preparations, sodium alginate serves as a common thickening and suspending agent in various types of pastes[13].

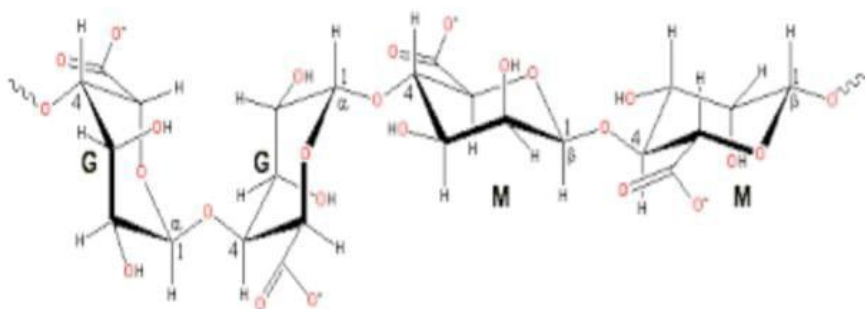


Fig 7:-alginate

CLASS 2:- PROTIEN

a) Wheat gluten.

*Composition :-Wheat gluten is composed of two primary types of proteins: gliadin and glutenin. Gliadins are protein molecules characterized by low molecular weight, a low proportion of amino acids with charged side groups, and the presence of disulfide bonds. Glutenins are more complex proteins, possessing a three-dimensional structure. Their molecular weight is at least tenfold greater than that of gliadins.

* Application:- Wheat gluten has shown to be a superb film forming agent.



Fig 9:-wheat gluten

B) soy protein

*Composition :- The most purified type of soy protein is soy protein isolate, which consists of around 90% protein. Essentially, soy protein concentrate is soybean that lacks the water-soluble carbohydrates. It consists of roughly 70 percent protein.

*Application :- Since 1959, it has been utilized in various food products due to its functional properties, such as emulsification and texturizing. The popularity of soy protein has been rising recently, primarily due to its health benefits. It has been demonstrated that soy protein can aid in the prevention of heart issues.



Fig 10:-soy protein

ii. PROTEIN FROM ANIMAL ORIGIN.

a)collagen.

*Composing :-There are 27 types of collagen, each made up of different polypeptides that primarily consist of glycine, proline, hydroxyproline, and lysine. Only the glycine content determines how flexible the collagen chain

*Applications :- In ophthalmology, collagen films serve as drug delivery systems that facilitate the slow release of their embedded medications. It was also utilized in tissue engineering for skin replacement, bone substitutes, and artificial blood vessels and valves.

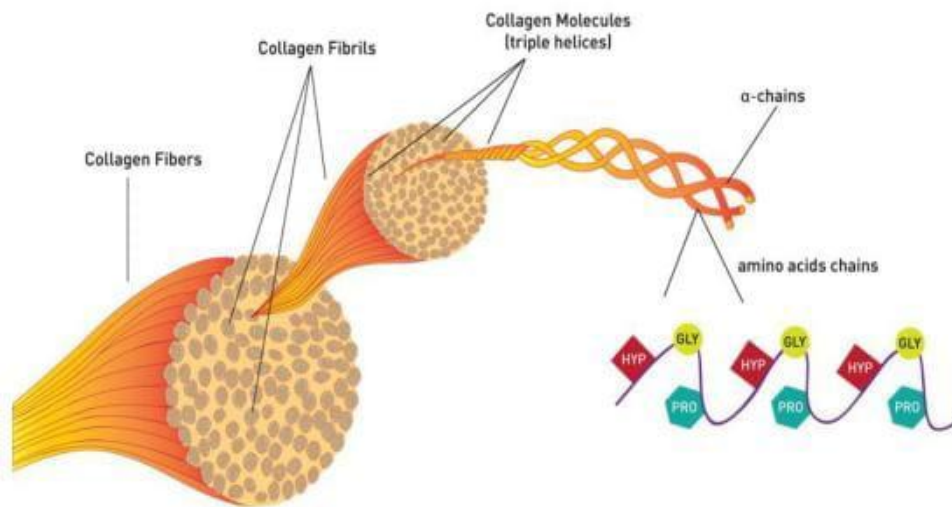


Fig 11:-collagen

C) Gelatine

*Composition:-Collagen can be denatured and/or undergo physical-chemical degradation to produce a high molecular weight polypeptide known as gelatin⁴⁰. Gelatin, which is also a protein, is made up of 19 amino acids⁴¹. It can dissolve in water. Weitere tierische Proteine sind Elastin, Albumin und Fibrin.

*Applications:-Emulsifiers, foaming agents, colloid stabilizers, biodegradable film-forming materials, and microencapsulating agents are among these widely used^[14].

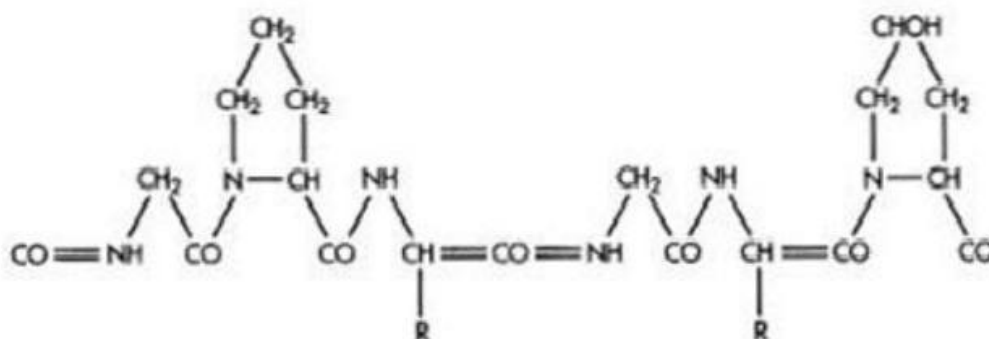


Fig 12:- gelatine



FORMULATION OF SUSTAINED RELEASE TABLETS

***Direct Compression:** This method, which is both uncomplicated and inexpensive, can be used to create sustained-release matrix tablets. The active pharmaceutical ingredient (API) is combined with excipients, mainly polymers that create the matrix, during this process. A tablet press is then used to compress the mixture directly into tablets. This approach is appropriate for drugs that have good flow and compressibility characteristics. Agents that are typically utilized for forming matrices include polymers like hydroxypropyl methylcellulose (HPMC), ethyl cellulose, and polyvinyl alcohol.

***Wet Granulation:** This process entails mixing the drug and excipients with a liquid binder to create granules, which are subsequently dried and compressed into tablets. This approach improves the flowability and compressibility of the drug-polymer mixture, which helps to achieve a consistent drug content in the matrix tablets. A binder, like povidone, starch paste, or hydroxypropyl cellulose, is essential for binding the particles together. Depending on the desired release profile, the polymers utilized in wet granulation may consist of hydrophilic or hydrophobic materials. Although tablets produced via wet granulation exhibit enhanced mechanical strength, this method necessitates extra steps and equipment, rendering it more time-consuming and costly than direct compression

*** Melt Granulation:** This is a solvent-free method where a polymeric binder is heated until it melts and then combined with the drug and excipients to create granules. As a granulating agent, the molten binder removes the necessity for water or organic solvents. Commonly used are hydrophobic polymers like glyceryl monostearate, carnauba wax, or polyethylene glycol (PEG). Afterward, the granules are cooled down, sieved, and formed into tablets through compression. Melt granulation is especially advantageous for creating sustained release formulations that utilize hydrophobic matrix systems. Moreover, it circumvents problems concerning the extraction of solvent, which renders it a method that is comparatively gentle on the environment. Nevertheless, the application of heat can restrict its use for drugs that are sensitive to heat.

*** Coating Technique:** -Coating techniques are used to manage the release of medication by putting a polymer layer on top of an immediate-release core tablet. Depending on the desired release profile, the coating material can be hydrophilic, hydrophobic, or pH-sensitive. Methods like fluidized bed coating, dip coating, or pan coating are frequently employed. It is common to use polymers such as ethyl



cellulose, Eudragit, or HPMC. Coated matrix tablets are particularly effective for attaining delayed or pulsatile drug release. Nonetheless, specialized equipment and precise control of parameters are necessary for the coating process to ensure uniformity and reproducibility, which can lead to higher manufacturing costs.

***Ion Exchange Resins** :- This method involves creating a drug-resin complex by binding the drug to ion-exchange resins. While the drug passes through the gastrointestinal tract, it is released in response to alterations in the ionic environment, including changes to pH or electrolyte concentration. The resins function as a matrix system, guaranteeing a sustained release of the drug. This method is especially beneficial for medications that are prone to enzymatic degradation or have narrow absorption windows. Although ion-exchange systems provide exact release control, they necessitate comprehensive formulation optimization to guarantee stability and reproducibility[15,16].

EVALUATION OF SUSTAIN RELEASE TABLET

1. FT-IR Spectroscopy
2. Tablet Thickness
3. Tablet Hardness
4. Friability

1.FTIR spectroscopy

The Fourier transform infra-red spectroscopy of the drug, polymers, and their physical mixtures was conducted using a Shimadzu FTIR spectrophotometer with the KBr pellet technique. The instrument was used with a dry air purge, and the scan was taken at a scanning speed of 2 mm/sec and a resolution of 4 cm^{-1} over the range of $4500\text{--}400\text{ cm}^{-1}$. The identified peaks were matched with the main peaks of the reported FT-IR spectrum to authenticate the sample[17].

2. Tablet Thickness

The thickness of the tablet is assessed using a micrometer screw gauge. Twenty tablets are tested randomly, and average values are computed[18].



3. Hardness

For tablets from every batch, a hardness test was performed using a Monsanto hardness tester, after which average values were determined[19].

4. Friability.

Using a Roche friabilator [Campbell Electronics, Mumbai, India] [n = 20], the friability of the prepared formulations was assessed. The samples of tablets corresponding to 6.5 g were precisely weighed, located in the drum. After the drum made 100 revolutions, the tablets were taken out. Any loose dust from the tablets was eliminated, an accurate weight was recorded, and the % friability was computed based on the weights of the tablets before and after the test[20].

5. In vitro drug release from tablet

Drug release studies were performed using a USP-22 dissolution apparatus-2 with a paddle type (Electrolab, Mumbai, India), rotating at 50 rpm and maintaining a temperature of $37 \pm 0.5^\circ$. The dissolution media consisted of 900 ml of 0.1 mol/l HCl for the initial 2 hours, after which a pH 6.8 phosphate buffer solution was used for 12 hours. The sink condition was upheld throughout the entire experiment. At regular intervals, samples (10 ml) were taken out and the same volume of pre-warmed ($37 \pm 0.5^\circ$) fresh dissolution medium was added to keep the volume constant. Samples that were withdrawn were passed through a $0.45 \mu\text{m}$ membrane filter (Nunc, New Delhi, India). The drug content of each sample was analyzed using a UV spectrophotometer (Shimadzu UV-1700) at 233 nm after suitable dilution[21].

CHARACTERISTICS AND EVALUATION OF GRANULES

1 Angle of repose

2 Bulk density

3 Compressibility index

1 Angle of repose :-The funnel method was used to determine the granules' angle of repose. Granules with the correct weight were placed in the funnel. The funnel was adjusted to a height where its tip just



made contact with the apex of the powder blend. The granules were permitted to move through the funnel freely onto the surface¹³. The granules' cone diameter was measured, and the angle of repose was determined using the equation below.

$$\tan \theta = h/r,$$

where h represents the height of the powder cone.

r = radius of the conical powder[22].

2 Bulk density: The bulk density of a powder is determined by dividing its mass by the bulk volume, with the result expressed in gm/cm³. The formula used for the calculation of bulk density was:

$$\text{Bulk Density} = M / V_o$$

Where M represents the weight of the sample

V_o = apparent powder volume[23].

3 Compressibility index :- Carr created an indirect method for assessing powder flow based on bulk densities. A low Carr's index indicates that the primary packing arrangement is effective and there are fewer voids in the volume. The flow of powder diminishes as the values of these indices increase[24].

ADVANTAGES OF NATURAL POLYMER

The following are only a few of the many benefits of natural plant-based materials.

(1) Biodegradable: Because they are created by all living organisms and are naturally occurring, they are biodegradable.

(2) Non-toxic and biocompatible: These plant components are essentially repeating sugar polysaccharides.

(3) Low cost: Using them as natural sources is less expensive. The cost of manufacture is lower than that of synthetic materials. Agriculture is the main source of income for India and many other developing nations, and it receives significant financial investment.



(4) Eco-friendly processing: Because of the straightforward production methods, a wide variety of natural chemicals derived from various plant sources are used extensively in the pharmaceutical sector and gathered in incredibly enormous numbers.

(5) Local availability (particularly in developing countries): The government of India and other homogeneous developing nations promotes the production of plants as pharmaceutical excipients and also provides the facilities for bulk production, such as gum and mucilages, due to their numerous industrial uses.

(6) Public acceptance and patient tolerance: Natural materials are less likely to have negative side effects than synthetic ones.

DISADVANTAGES OF NATURAL POLYMER

While there are certain better benefits to natural polymers, there are also some drawbacks that should be taken into account. The most typical drawbacks are:

1. There may have been microbial contamination.
2. There is fluctuation from batch to batch.
3. There is no control over the rate of hydration.
4. The formulation's viscosity decreased as it was being stored.
5. Seasonality characterizes most natural polymers[25].

NATURAL POLYMER APPROACH IN SUSTAINED RELEASE DRUG DELIVERY SYSTEM

Research on the delivery of drugs using natural polymers and their semi-synthetic derivatives is still ongoing. In matrix systems, drug-release retarding polymers are crucial. Numerous polymers, each with a unique approach to the matrix system, have been studied as drug-retarding agents. Matrix systems are often divided into three primary categories based on the characteristics of the retarding polymer: hydrophilic, hydrophobic, and plastic. The best polymers for delaying drug release are hydrophilic ones, and their use in sustained drug administration is becoming more and more



popular. Numerous natural polymers, including hibiscus mucilage, have been studied as sustained release agents. The fresh leaves of *Hibiscus rosa-sinensis* are used to remove the mucilage. Known by many as the "China rose," *Hibiscus rosa-sinensis*, a member of the Malvaceae family, is a popular landscaping shrub that may reach heights of 7 to 12 feet. Its medium-textured, glossy, dark green leaves give a striking look, as do its spectacular flowers, which are 4 to 6 inches broad and up to 8 inches long. Diclofenac sodium matrix tablets were designed and their release retardant activity in manufactured sustained release formulations was investigated utilizing mucilage from *Hibiscus rosa-sinensis* leaves. The physicochemical characteristics of *Hibiscus rosa-sinensis* leaves were assessed. Diclofenac sodium tablets made from the mucilage of *Hibiscus rosa-sinensis* leaves were prepared. The weight, hardness, friability, and drug content of the matrix tablets were found to be more uniform with low deviating values. The mucilage from dried *Hibiscus rosa-sinensis* leaves can be utilized as a matrix-forming material to create sustained release matrix tablets, as demonstrated by the swelling behavior, release rate characteristics, and in vitro dissolution studies. The chosen formulation's kinetics were zero order. The mucilage from *Hibiscus rosa-sinensis* leaves was found to be a useful matrix-forming polymer for maintaining the release of Diclofenac sodium from the formulation.

1 Aloe mucilage

2 Fenugreek Mucilage

3 mimosa pudica mucilage

4 Hibiscus mucilage

5 orka gum

1. Aloe mucilage :-

Numerous chemicals with a variety of structures have been isolated from the central parenchyma tissue of *Aloe vera* leaves as well as the exudates produced by the cells next to the vascular bundles in the inner portion of *Aloe vera* (L.) Burm.f. (*Aloe barbadensis* Miller) leaves. 1,8-dihydroxyanthraquinone derivatives and their glycosides⁷ are present in the bitter yellow exudates. In addition to the various carbohydrates, it has been demonstrated that the *aloe* parenchyma tissue or pulp contains proteins, lipids, amino acids, vitamins, enzymes, inorganic chemicals, and tiny organic molecules. Several



researchers have determined that the main polysaccharide of the gel is partially acetylated mannan (also known as acemannan), while others have discovered that pectic material is the main polysaccharide.

2.Fenugreek Mucilage :-

Fenugreek, or *Trigonella Foenum-graceum*, is a herbaceous plant of to the leguminous family. Mucilage, a naturally occurring sticky material found in many seed coverings, makes up a large portion of fenugreek seeds. Mucilage does not dissolve in water, but when it comes into contact with liquids, it turns into a sticky, viscous substance. Fenugreek seeds swell and turn slippery when they come into contact with liquids, just like other materials that contain mucilage. In order to separate the husk from the seeds, the size-reduced seeds are first suspended in chloroform for a while before being decanted. The oily part is extracted using chloroform and subsequently air dried. There are also reports of an alternative extraction method for separating the mucilage from the husk. Hexane is used to extract the powdered seeds, which are then cooked in ethanol. After being soaked in water, the treated powder is mechanically agitated and filtered. After centrifugation, the filtrate is concentrated under vacuum and combined with 96% ethanol. After that, it is refrigerated for four hours in order to precipitate the mucilage¹³. The use of fenugreek seed mucilage in matrix compositions containing propranolol hydrochloride was examined in one study. For comparison, Methocel[®] K4M was utilized as a typical controlled release polymer.

3.Mimosa pudica mucilage:-

The sensitive plant, *Mimosa pudica* (family Mimosaceae), is a spreading undershrub that is widely distributed throughout India's tropical and subtropical regions. Mucilage from *M. pudica* seeds is made up of d-xylose and d-glucuronic acid. When mimosa seed mucilage comes into contact with water, it quickly hydrates and expands. The dissolving and binding characteristics of Mimosa seed mucilage were assessed in a previous work conducted in our lab. Using diclofenac sodium (DS) as a model medication, we have isolated, characterized, and assessed the sustained-release characteristics of Mimosa seed mucilage. The wet granulation method was used to formulate the DS matrix tablet, which was then assessed for appearance, weight variation, hardness, friability, in vitro drug release, swelling, and erosion behavior.



4. Hibiscus Mucilage:-

Mucilage, which provides long-lasting activity, is extracted from fresh *Hibiscus rosa-sinensis* leaves. (Malvaceae family). L-rhamnose, D-galactose, D-galacturonic acid, and D-glucuronic acid are among the chemical components found in *Hibiscus rosa-sinensis* mucilage. There have been reports of using its mucilage to create sustained-release pills.

5. Okra gum:-

Abelmoschusculentus (Fam. Malvaceae) is the botanical name for this tall, upright annual plant. In the majority of Nigeria's tropical regions, it is extensively grown. throughout addition to being used as food and soup throughout Asia and Africa, okra has been the focus of agricultural and culinary research. When okra is crushed and extracted in water, a viscous mucilaginous solution is produced. Okra gum's potential as a pharmaceutical excipient has been discussed in literature as a binder, control release, film coating, bio-adhesive, and suspending agent. Using paracetamol as a model medication, okra gum has been assessed as a controlled-release agent in modified release matrices in contrast to sodium carboxymethylcellulose (NaCMC) and hydroxyl-propyl-methylcellulose (HPMC). Direct compression was used to create tablets, and the in-vitro drug release was evaluated for six hours under settings that resembled the gastrointestinal tract. For over six hours, okra gum matrices offered a regulated release of paracetamol, with release rates that followed time-independent kinetics. The drug's concentration within the matrix determined the release rates. The release kinetics and dissolution process were changed by the inclusion of tablet excipients, lactose and Avicel[26,27,28].

FUTURE PERSPECTIVE

The development of drug-delivery vehicles utilizing synthetic and natural polymers is a field of study that is progressing quickly. The most notable advancements in polymeric drug delivery are being made in the field of responsive delivery systems, which enable the tailored administration of medications based on certain sites or blood level monitoring. The researchers anticipate a number of uses for these copolymers, including lining prosthetic organs, performing immunological tests, acting as drug-targeting agents, operating in chemical reactors, and offering substrates for cell development. Implanted devices that accurately or locally distribute medications to target areas can be created using a particular polymeric system to achieve the right blood levels. Because biomimetic and bioinspired



systems can overcome a number of obstacles associated with polymeric drug delivery, they hold considerable potential for the future. It will have effectively enabled the incorporation of biocompatible and bio-related copolymers and dendrimers in cancer treatments, particularly in their role as carriers of powerful anti-cancer drugs like cisplatin and doxorubicin. Dendrimers' unique characteristics, such as their well-defined molecular weight, globular topology, high degree of branching, and multivalence, make them a promising novel scaffold for polymeric drug delivery systems. The creation and synthesis of new polymers may enable us to use a greater variety of polymer combinations in future drug delivery systems[29].

CONCLUSION

Natural polymers play a vital role in the development of modern drug delivery systems due to their biocompatibility, biodegradability, and ability to control the rate and duration of drug release. Materials such as carrageenan, pectin, glucomannan, cellulose, agar, and xanthan gum have demonstrated excellent potential in sustained and controlled release formulations. Their capacity to swell, form gels, and interact with drugs allows for precise modulation of release kinetics, thereby maintaining therapeutic drug levels for extended periods. Sustained release tablets formulated with these polymers not only enhance treatment effectiveness but also improve patient compliance by reducing dosing frequency and minimizing side effects. The physicochemical properties of each polymer—such as solubility, viscosity, and molecular structure—significantly influence the release behavior and stability of the dosage form. Ongoing research continues to focus on optimizing natural polymer-based systems and combining them with synthetic polymers to achieve more efficient, site-specific, and responsive drug delivery. In the future, biomimetic and bioinspired polymer systems are expected to revolutionize targeted therapy, particularly in chronic and cancer treatments, by offering safe, reliable, and controlled drug release mechanisms. Thus, natural polymers represent a sustainable and promising foundation for the advancement of next-generation pharmaceutical technology.

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ANTAGONISTIC EFFECT OF TRICHODERMA SPP.AGAINST C.COCCOIDES

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ABSTRACT

The infected Samples of Tomato anthracnose collected from different fields of Marathwada region like Beed, Gangapur, Paithan, and Jalna during academic year 2024-2025 crop seasons. Isolation of pathogen was done by inoculating the samples on Rose Bengal agar medium and the cultures were further Purified and maintained on potato dextrose agar medium at 26+10C.The isolate of *C.coccoides* was selected for the purpose of integrated management under antagonism by different fungal antagonistic isolates. *Trichoderma atroviride*, *T.harzianum*, *T.viride*. Among them *Trichoderma atroviridi* and *T.harzianum* were found to be effective.

KEYWORDS

Anthrachnose, C. coccoides, Trichoderma

INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is an important vegetable as well as nutritive crop, cultivated worldwide It is not only used in many cuisines but also found to have many medicinal properties Tomato (*Solanum lycopersicum* L.) is valued for its diverse commercial uses throughout world. India is major producer, consumer and exporter of Tomato *Colletotrichum coccoides*, India had been the largest producer and exporter of tomato, but since a few years the production has declined significantly and presently, India stands at the third number in terms of tomato production ([FAOSTAT, 2012](#)) as the most predominant species in the major Tomato growing states namely Karnataka State and Andra Pradesh (Rama chandran et al. 2008). Anthracnose is a major problem on mature leaves and fruits, causing severe losses due to both pre-harvest and post-harvest fruit decay (Hadden JF, Black LL., 1989) *Trichoderma spp.* have been known as biocontrol agents (BCA) for the control of plant diseases for decades (Weindling, 1932; Harman et al., 2004).

METHODOLOGY

- 1) The infected samples of Tomato anthracnose collected from different fields of Marathwada region like Beed, Gangapur, Paithan, and Jalna during 2024-25 crop season.
- 2) Isolation of pathogen was done by inoculating the samples on Rose Bengal agar medium and the cultures were further purified and maintained on potato dextrose agar medium at 26+1°C
- 3) The isolate of infected fruits of tomato was selected for the purpose of integrated management under antagonism by different fungal antagonistic isolates. *Trichoderma atroviride*. *T.harzianum-1*, *T.harzianum-2*, *T viride*
- 4) To study the antagonistic effect, an experiment was laid out in Petri plates poured with sterilized Czapek Dox Agar Solidified medium in the plates was inoculated by placing the discs (4 mm diameter) of bio-agents culture and exacting opposite to this disc of test fungus (7 days old culture) were placed in such a manner that both organisms would get equal opportunity for their growth.
- 5) The experiment was conducted with three replications and one control plate containing only test fungus.
- 6) The antagonistic effect of *Trichoderma* was assessed on the basis of pathogen mycelial on seventh day (Vincent 1947, Dennis and Webster 1971. Arora, D K and inhibition Upadhyay, R. K. 1978).

Per cent inhibition over control was calculated as per the formulae Eq. (1) by Vincent, (1947).

$$I = \frac{C-T}{C} \times 100$$

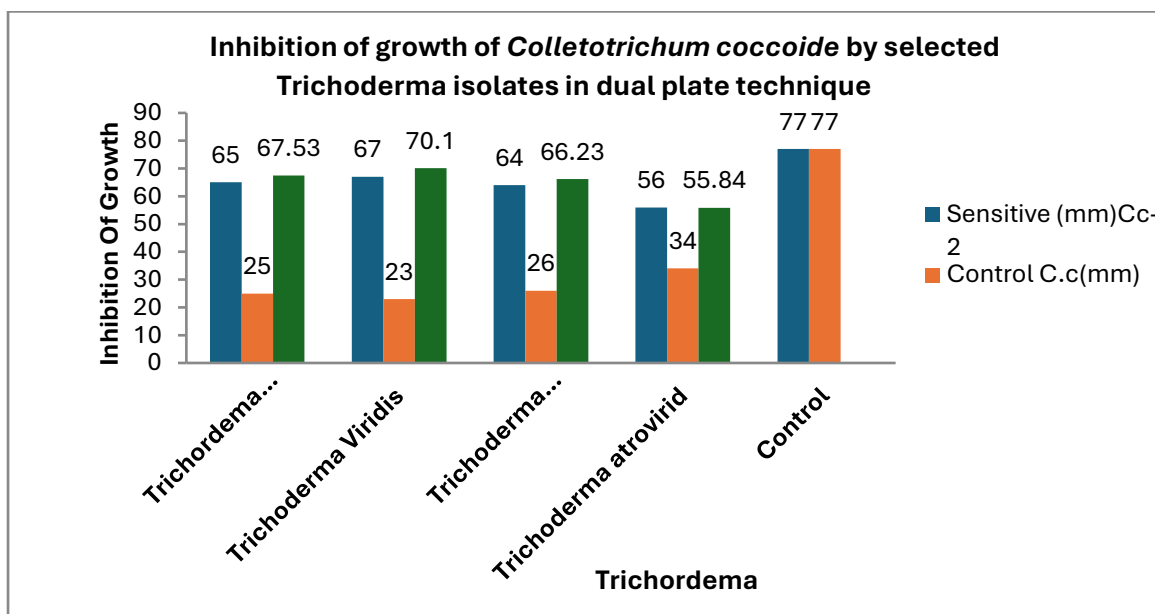
Where, I = Per cent inhibition over control

C=Growth of test pathogen with absence of antagonist (mm)

T= Growth of test pathogen with antagonist (mm)

RESULTS AND DISCUSSION

Sr. No.	Trichodermaspp.	C.coccoides	Cc-5 Resistant(mm)	PCE*
1	<i>Trichoderma harizianum-1</i>	21.8	68.22	71.68
2	<i>T. viride</i>	20.0	70.00	74.02
3	<i>T.harizianum-2</i>	20.0	70.00	74.02
4	<i>T. atroviride</i>	30.4	59.66	60.50
5	Control	77.0	--	--
	C.D. (P= 0.05)	16.89	6.20	3.34



The effect of seed and soil treatment with *Trichoderma harzianum* and *Trichoderma viride* were significantly effective against seed borne fungal pathogens including *Colletotrichum spp.* (RaoVCh. Narayana YD., 2010) The highly isolate of *C. coccoides* was selected for the purpose of integrated management under antagonism by different fungal antagonistic isolates. *Trichoderma atroviride*, *T harzianum-1*, *T harzianum-2*, *T viride* Among them *Trichoderma harzianum-2*, *T viride* were found to be effective *T viride* gave PCE 60. 10 to 74.02



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BIOLOGY AND MANAGEMENT OF TOMATO LEAF MINER (*TUTA ABSOLUTA MEYRICK, 1917*): A COMPREHENSIVE REVIEW.

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ABSTRACT

The tomato leaf miner, *Tuta absoluta* (Meyrick, 1917) (Lepidoptera: Gelechiidae), is one of the most destructive insect pests of tomato worldwide. Native to South America, this invasive pest has rapidly spread across Europe, Africa, the Middle East, and Asia, including India, causing severe yield losses ranging from 80–100% under uncontrolled conditions. Its endophytic feeding habit, high reproductive potential, multivoltine nature, and ability to develop resistance to insecticides make its management extremely challenging. This review synthesizes published research from reputed journals on the biology, distribution, damage symptoms, and management strategies of *T. absoluta*. Emphasis is placed on integrated pest management (IPM) approaches, including cultural, mechanical, biological, botanical, biotechnical, host plant resistance, and chemical control methods. The review highlights recent advances, challenges, and future research needs for sustainable management of *T. absoluta*, particularly under diverse agro-climatic conditions of developing countries.

KEYWORDS

Tuta absoluta, tomato leaf miner, Solanaceous crops, biology, integrated pest management, biological control, botanicals, pheromones

INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is one of the most important vegetable crops grown worldwide for fresh consumption and processing. It ranks among the top vegetable crops in terms of area and production, contributing significantly to food security, nutrition, and farm income. Tomatoes are rich sources of vitamins A, C, and E, minerals, and antioxidants such as lycopene, which is associated with reduced risks of cardiovascular diseases and certain cancers.



Despite its economic and nutritional importance, tomato production is severely constrained by insect pests and diseases. Among the insect pests, the tomato leaf miner, *Tuta absoluta* (Meyrick, 1917), has emerged as a major threat to tomato cultivation globally. Since its first detection outside South America in Spain in 2006, *T. absoluta* has spread rapidly across Europe, Africa, the Mediterranean basin, and Asia, including India, Bangladesh, and Nepal. In India, the pest was first reported in 2014 and has since established itself in almost all major tomato-growing states.

Biological invasions such as *T. absoluta* are increasingly facilitated by globalization, international trade, and climate change. Invasive arthropod pests pose serious challenges to sustainable agriculture due to their rapid spread, lack of effective natural enemies in new areas, and heavy reliance on chemical insecticides. Therefore, an integrated pest management (IPM) approach is essential for effective and environmentally sound management of *T. absoluta*.

2. Global Distribution and Invasion History

Tuta absoluta is native to South America and was first described from Peru in 1917. It later spread to several South American countries, including Brazil, Argentina, Chile, Colombia, and Venezuela. The pest was first detected in Europe in Spain in 2006 and subsequently spread throughout Southern Europe, North Africa, and the Mediterranean region.

In Africa, *T. absoluta* has been reported from countries such as Egypt, Ethiopia, Kenya, Sudan, and Nigeria, where it poses a serious threat to smallholder and commercial tomato production. In Asia, the pest has been recorded in Iran, Iraq, Israel, Turkey, India, Bangladesh, and Nepal. In India, its rapid spread across diverse agro-climatic regions has resulted in severe yield and quality losses, making it one of the most destructive tomato pests in recent decades.

3. Biology and Life Cycle

Table 1. Summary of biology and life cycle of *Tuta absoluta*

Life stage	Description	Duration (days)*	Key characteristics
Egg	Elliptical, creamy white to yellowish; laid singly or in clusters on underside of leaves, stems, buds and fruits	4–7	Female lays up to 250–260 eggs; incubation influenced by temperature

Larva	Four instars; whitish initially, later greenish or pinkish	10–15	Most destructive stage; mines leaves, stems and fruits
Pupa	Formed in soil, leaf mines or plant debris; green turning dark brown	5–10	Protected stage; survives adverse conditions
Adult	Small moth (~10 mm); silvery-grey scales; nocturnal	10–15 (adult longevity)	Active at night; responsible for mating and oviposition

*Duration varies with temperature and environmental conditions.

The life cycle of *T. absoluta* consists of four stages: egg, larva, pupa, and adult. The duration of the life cycle varies with temperature and host plant, typically completing in 24–38 days.

3.1 Egg

Eggs are small, elliptical, creamy white to yellowish, and laid singly or in small groups on the underside of leaves, stems, buds, or calyx of fruits. A single female can lay up to 250–260 eggs during her lifetime. Egg incubation period ranges from 4–7 days, depending on temperature.

3.2 Larva

Larvae pass through four instars and are the most destructive stage. Newly hatched larvae are whitish, later turning greenish or pinkish. Larvae mine leaves, stems, and fruits, forming galleries that reduce photosynthetic area and marketability of fruits. Larval development lasts 10–15 days.

3.3 Pupa

Pupation occurs either in the soil, within leaf mines, or on plant debris. Pupae are initially green and later turn dark brown. The pupal stage lasts about 5–10 days.

3.4 Adult

Adults are small moths, about 10 mm long, with silvery-grey scales and filiform antennae. They are nocturnal and remain hidden during the day. Adults live for 10–15 days, during which mating and oviposition occur.

4. Nature of Damage and Economic Importance

Tuta absoluta attacks tomato plants at all growth stages, from seedlings to fruiting plants. Larvae mine leaves, bore into stems, and penetrate fruits, making them unmarketable. Severe infestations can lead to 80–100% yield loss under favorable conditions. Apart from tomato, the pest can also infest other Solanaceous crops such as potato, brinjal, and capsicum, as well as several wild host plants.

5. Management Strategies

Table 2. Comparison of management strategies used against *Tuta absoluta*

Management approach	Tools/agents used	Mode of action	Advantages	Limitations
Cultural control	Crop rotation, removal of infested plant parts, deep ploughing, sanitation	Reduces pest carryover and breeding sites	Low cost, eco-friendly	Requires strict field hygiene
Mechanical/Physical control	Handpicking, light traps, insect-proof nets	Physical removal or exclusion	Safe, non-toxic	Labour intensive, limited efficacy alone
Biological control	<i>Trichogramma</i> spp., <i>Nesidiocoris tenuis</i> , <i>Dolichogenidea gelechiidivoris</i>	Parasitism and predation	Sustainable, long-term control	Slow establishment, climate dependent
Entomopathogenic fungi	<i>Beauveria bassiana</i> , <i>Metarhizium anisopliae</i>	Infection leading to larval mortality	Eco-friendly, compatible with IPM	Slower action, affected by humidity
Botanical pesticides	Neem, garlic, lemongrass extracts	Antifeedant, repellent, growth inhibition	Safe to non-targets, biodegradable	Variable efficacy
Biotechnical control	Sex pheromone traps	Monitoring, mass trapping, mating disruption	Species-specific, safe	Needs proper installation and maintenance



Chemical control	Chlorantraniliprole, indoxacarb, spinosad, emamectin benzoate	Nervous system disruption	Quick knockdown	Resistance development, harmful to natural enemies
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5.1 Cultural Control

Cultural practices play an important role in reducing pest populations. These include removal and destruction of infested plant parts, crop rotation with non-host crops, deep ploughing to destroy pupae, use of pest-free seedlings, and avoidance of continuous tomato cultivation.

5.2 Mechanical and Physical Control

Mechanical methods such as handpicking of infested leaves and fruits, use of light traps, and installation of insect-proof nets in nurseries and greenhouses can help reduce infestation levels.

5.3 Biological Control

Biological control is a key component of IPM for *T. absoluta*. Several natural enemies, including parasitoids (*Trichogramma* spp., *Dolichogenidea gelechiidivoris*), predators (*Nesidiocoris tenuis*), and entomopathogenic fungi (*Beauveria bassiana*, *Metarhizium anisopliae*), have shown promising results. Conservation and augmentation of these natural enemies can significantly suppress pest populations.

5.4 Botanical and Biopesticides

Botanical pesticides such as neem (*Azadirachta indica*), garlic (*Allium sativum*), and lemongrass (*Cymbopogon citratus*) extracts have shown insecticidal, antifeedant, and repellent effects against *T. absoluta*. Entomopathogenic fungi have also demonstrated substantial larval mortality under field conditions, offering eco-friendly alternatives to chemical insecticides.

5.5 Biotechnical Control

Pheromone-based tools, including sex pheromone traps, are widely used for monitoring, mass trapping, and mating disruption. These methods are effective, species-specific, and environmentally safe.

5.6 Chemical Control

Chemical insecticides such as chlorantraniliprole, indoxacarb, spinosad, emamectin benzoate, and Bt formulations have been used against *T. absoluta*. However, indiscriminate use has led to the



development of resistance and negative impacts on natural enemies. Therefore, chemical control should be used judiciously and in rotation with other management strategies.

6. Integrated Pest Management (IPM)

An effective IPM strategy for *T. absoluta* involves the integration of cultural, mechanical, biological, botanical, biotechnical, and chemical methods. Regular monitoring, use of economic threshold levels, conservation of natural enemies, and farmer awareness are essential components of successful IPM programs.

CHALLENGES AND FUTURE PROSPECTS

Major challenges in managing *T. absoluta* include rapid resistance development, lack of awareness among farmers, limited availability of biological control agents, and variability in climatic conditions. Future research should focus on developing resistant tomato varieties, improving biological control efficiency, and strengthening IPM adoption at the farmer level.

CONCLUSION

Tuta absoluta continues to pose a serious threat to global tomato production. Sustainable management of this pest requires a holistic IPM approach that minimizes reliance on chemical insecticides and promotes eco-friendly alternatives. Continued research, extension efforts, and policy support are crucial for mitigating the impact of this invasive pest and ensuring sustainable tomato production.

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GREEN-SYNTHESIZED METAL NANOPARTICLES IN POULTRY PRODUCTION: ANTIMICROBIAL PROPERTIES, STRESS MANAGEMENT, AND GROWTH ENHANCEMENT

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ABSTRACT

Nanotechnology presents groundbreaking approaches to tackle antimicrobial resistance, improve stress management, and boost productivity in agriculture. This review consolidates findings on environmentally-friendly synthesized silver (Ag), copper (Cu), and iron (Fe) nanoparticles, exploring synthesis techniques, characterization, antimicrobial characteristics, and their applications in poultry. The use of mint (*Mentha* spp.), basil (*Ocimum basilicum*), and pomegranate peel in green synthesis offers eco-friendly alternatives to traditional chemical methods. Silver nanoparticles exhibit significant antimicrobial properties, with a minimum inhibitory concentration of 2.49 µg/mL against *Escherichia coli*, along with protective effects against aflatoxin. Copper nanoparticles improve stress adaptation, intestinal structure, and antioxidant levels in response to cold stress. Iron oxide nanoparticles enhance growth performance by 15.8% in body weight and effectively decrease ammonia emissions during heat stress, utilizing doses that are 60-80% lower than traditional sources. Nonetheless, it is essential to conduct a thorough assessment of tissue accumulation and oxidative stress. This review highlights the potential of green-synthesized nanoparticles as sustainable alternatives to antibiotic growth promoters, while also pinpointing existing knowledge gaps in mechanistic understanding, standardization, and regulatory frameworks.

KEYWORDS

green synthesis; nanoparticles; mint extract; poultry production; antimicrobial activity; stress management



INTRODUCTION

The global agriculture and poultry sectors encounter significant challenges such as antimicrobial resistance, environmental stressors, mycotoxin contamination, and the necessity to meet food demands in a sustainable manner. Traditional methods such as antibiotic growth promoters have sparked worries regarding the emergence of resistance and environmental contamination (Gunal et al., 2006; Havenstein et al., 2003). The 2006 ban by the European Union on antibiotic growth promoters, as outlined in Regulation (EC) No. 1831/2003, required the development of alternative strategies.

Nanotechnology presents a transformative approach characterized by improved bioavailability, precise delivery, regulated release, and minimized environmental effects (Ahmadi & Rahimi, 2011; Remya et al., 2017). Metal nanoparticles (1-100 nm) display unique physicochemical characteristics such as elevated surface area-to-volume ratios, heightened reactivity, enhanced cellular uptake, and innovative optical properties (Tsekhmistrenko, 2024), allowing for supplementation at reduced doses while achieving superior biological effects.

Silver, copper, and iron nanoparticles exhibit significant antimicrobial effects and play crucial nutritional roles. The use of plant extracts, microorganisms, or agricultural by-products in "green synthesis" as reducing and stabilizing agents presents advantages such as environmental sustainability, cost-effectiveness, biocompatibility, and improved biological properties (Khan et al., 2013; Remya et al., 2017). Plant extracts abundant in polyphenols, flavonoids, and terpenoids play a dual role in the reduction of metal ions and the stabilization of nanoparticles.

2. Green Synthesis Methods and Characterization

2.1 Fundamental Concepts and Botanical Resources

Green synthesis utilizes biological materials as reducing and stabilizing agents, thereby removing toxic chemicals and reducing the high energy consumption associated with traditional methods (Tsekhmistrenko, 2024). Plant-derived compounds such as polyphenols, flavonoids, and terpenoids play a crucial role in the reduction of metal ions and contribute to the stabilization of colloids through surface capping (Remya et al., 2017).



Mint extracts (*Mentha piperita*, *M. arvensis*) that are abundant in polyphenols (9.81 mg/mL) facilitate the production of silver and copper nanoparticles. FTIR analysis indicates the presence of hydroxyl ($3349\text{-}3404\text{ cm}^{-1}$), carbonyl ($1597\text{-}1646\text{ cm}^{-1}$), and C-O stretching ($1048\text{-}1108\text{ cm}^{-1}$) groups involved in reduction and stabilization. The process of synthesizing silver nanoparticles entails the combination of mint extract with 1 mM AgNO_3 at a temperature of 30°C for a duration of 24 hours, as verified by UV-Vis spectroscopy, which shows peaks in the range of 400-470 nm. Basil (*Ocimum basilicum*) extract yields iron oxide nanoparticles with an average size of 40 nm, whereas pomegranate peel, containing 9.33% tannin, synthesizes silver nanoparticles also measuring 40 nm, exhibiting a zeta potential of -29 mV and demonstrating excellent stability (Al-Othman et al., 2017).

2.2 Characterization

The synthesis is confirmed by UV-Visible spectroscopy, which shows surface plasmon resonance at 400-470 nm for AgNPs and 275-285 nm for CuO. XRD analysis indicates the presence of crystalline structures: silver exhibits a face-centered cubic (FCC, JCPDS 04-0783, 4.1-25 nm crystallites), while copper oxide displays a monoclinic structure (JCPDS 00-000-0661, 2.8-19.08 nm). TEM and SEM demonstrate a variety of morphologies, including spherical, triangular, and hexagonal shapes, ranging from 10 to 50 nm. The dynamic light scattering technique provides measurements of hydrodynamic diameter ranging from 49 to 53 nm, alongside zeta potential values between -20 and -23 mV, indicating stability. EDX verifies the elemental composition, indicating silver content ranging from 41.40% to 67.98%. The green synthesis method yields larger particles, measuring 12.2 nm compared to 3.5 nm from thermochemical processes, and does so at significantly lower temperatures of 60°C versus over 300°C , while also demonstrating enhanced environmental compatibility (Tsekhmistrenko, 2024).

3. Silver Nanoparticles: Antimicrobial Properties and Applications

3.1 Antimicrobial Efficacy

Silver nanoparticles exhibit significant antimicrobial properties via multiple synergistic mechanisms, offering broad-spectrum effectiveness against a variety of pathogens. The minimum inhibitory concentration (MIC) values against Gram-negative bacteria, including *Escherichia coli*, can be as low as $2.49\text{ }\mu\text{g/mL}$, indicating a competitive edge over traditional antibiotics such as kanamycin. The MIC



for Gram-positive *Staphylococcus aureus* varies between 11.1 and 51.5 $\mu\text{g}/\text{mL}$, which highlights the significant protective benefit provided by their considerably thicker peptidoglycan layers (20-80 nm, in contrast to the 7-8 nm thickness found in Gram-negative bacteria) (Al-Saeedi et al., 2021; Faizan et al., 2024). The antimicrobial action of silver nanoparticles functions through various interconnected mechanisms. These include membrane disruption due to the electrostatic attraction between positively charged nanoparticles and negatively charged bacterial cell walls, DNA damage that interferes with replication processes, enzyme inhibition impacting essential ATP production pathways, the generation of reactive oxygen species (ROS) that cause lethal oxidative damage to cellular components, and the continuous release of silver ions that enhance these antimicrobial effects. In addition to their effects on bacterial targets, AgNPs exhibit notable antifungal properties by suppressing the growth of *Aspergillus flavus* and significantly reducing aflatoxin production (Zhao et al., 2017). Copper oxide nanoparticles demonstrate significant antifungal activity, showing inhibition zones of 1.5 cm against *Candida albicans*, which is the highest efficacy recorded among all microorganisms tested.

3.2 Poultry Production Effects

The administration of AgNPs enhances growth performance in a dose-dependent manner. In broilers receiving 20-50 ppm via drinking water, there was a significant increase in beneficial *Lactobacilli* populations in the jejunum and ileum at 40-50 ppm (14 and 42 days), while *E. coli* populations decreased dramatically, with 50 ppm resulting in the lowest counts (Al-Saeedi et al., 2021). In rabbits subjected to heat stress at 33°C, the administration of subcutaneous AgNPs at a dosage of 0.5 mg/kg resulted in a notable enhancement of final body weight.

The effects on the immune system are intricate and vary with dosage. Administration of AgNPs (5 mg/kg orally) resulted in an increase in phagocytic activity, leukocyte metabolic activity, and lysozyme activity after 24 days (Ognik et al., 2016). Intermediate concentrations could potentially hinder bursa development by disrupting the microbial balance, whereas elevated concentrations (50 ppm) might lead to toxicity.



3.3 Safeguarding Against Aflatoxin and Ensuring Safety

In broilers exposed to aflatoxin (70 ppm), the addition of AgNPs (150 ppm) resulted in a reduction of aflatoxin levels from 1.91 to 1.86 ppm and led to a significant decrease in liver damage, including congestion, thrombus formation, sinusoid dilatation, bile duct hyperplasia, necrosis, edema, and hemorrhage (Jasim & Al-Tae, 2023). Protection mechanisms encompass direct adsorption, interference with absorption, antioxidant properties, and improved hepatic detoxification.

Concerns regarding safety encompass oxidative stress and the accumulation of tissue. AgNPs (22 nm) resulted in a reduction of SOD and CAT activities, an increase in lipid peroxidation markers (LOOH, MDA), and a rise in cholesterol/LDL levels (Ognik et al., 2016). Silver residues accumulated in rabbit plasma and meat in a dose-dependent manner, showing variations among different breeds (Abdelsalam et al., 2019). Given that silver is not a necessary nutrient, the presence of tissue residues poses significant food safety issues.

4. Copper Nanoparticles: Analyzing Stress Management and Metabolic Support

4.1 Effects of Cold Stress

Copper plays a crucial role in metabolism, immunity, and antioxidant defense via Cu-Zn SOD. Conventional sources exhibit restricted bioavailability as a result of phytate binding. Nanoparticles improve absorption by increasing surface area and facilitating interactions with transporters such as DMT1 and CTR1 (Abdullah et al., 2022).

In Hubbard broilers subjected to cyclic cold stress ($13^{\circ}\text{C}\pm 2^{\circ}\text{C}$, 8 hours daily, days 22-35), the addition of CuNP (5, 10, 15 mg/kg, 25 nm size) enhanced body weight and feed conversion relative to cold-stressed controls, with the most significant effects observed at 15 mg/kg (Abdullah et al., 2022). CuNPs influenced thyroid metabolism by linearly decreasing T3 levels while increasing T4, indicating enhanced metabolic efficiency that reduces the necessity for excessive T3 elevation.

4.2 Gastrointestinal Well-being and Oxidative Defense

Cold stress led to a decrease in villus height, villus surface area, and the VH:CD ratio throughout the intestinal segments. CuNP supplementation led to a notable enhancement in intestinal morphometry



in a dose-dependent manner, exhibiting linear increases ($p < 0.05$) in villus height, width, crypt depth, and surface area across all segments. The group receiving 15 mg/kg exhibited the highest values. There was an observed increase in goblet cell populations within the jejunum and ileum, especially those producing acidic mucins that contribute to microbial defense (Abdullah et al., 2022).

CuNPs enhanced antioxidant status, showing a linear increase in SOD activity while MDA levels decreased linearly with dosage. Improved copper bioavailability facilitated the synthesis of Cu-Zn SOD, thereby bolstering antioxidant defenses. Serum corticosterone exhibited a linear decrease with supplementation, suggesting a diminished stress response (Abdullah et al., 2022).

5. Iron Oxide Nanoparticles: Growth Enhancement and Environmental Benefits

5.1 Growth Performance Under Heat Stress

Iron plays a crucial role in oxygen transport, as hemoglobin comprises 60-70% of the body's iron. It is also vital for enzyme activation, energy metabolism, and antioxidant defense mechanisms. Heat stress negatively affects feed intake, growth, immunity, and meat quality, while also leading to decreased iron concentrations (Almeldin et al., 2024). Traditional iron supplementation encounters difficulties due to phytate binding. Nanoparticles address these challenges by improving absorption capabilities.

In Ross 308 broilers subjected to heat stress (34.5°C/45% RH from days 1-21; 28.5°C/40% RH from days 22-42), the administration of green iron oxide nanoparticles (20, 40 mg/kg) resulted in a linear enhancement of body weight ($R^2=0.574$) and weight gain ($R^2=0.367$) by day 42. The 40 mg/kg dose resulted in 2,245.3 g compared to 1,939.5 g in the controls, indicating a 15.8% improvement. Body weight gain increased by 16.15% with a dosage of 40 mg/kg. The feed conversion ratio showed consistent improvement across all periods ($R^2=0.424$), with the 20 mg/kg treatment yielding the most efficient FCR at 1.455, representing a 14.56% enhancement compared to the control group at 1.703. The feed intake remained consistent, suggesting improved nutrient utilization (Almeldin et al., 2024).

5.2 Environmental Benefits and Meat Quality

The application of Nano-Fe led to a notable decrease in excreta ammonia content ($R^2=0.454$) at both 21 and 42 days, with the lowest levels observed at a dosage of 40 mg/kg. This reduction enhances



animal welfare and promotes environmental sustainability by mitigating respiratory diseases, atmospheric pollution, acid rain, and eutrophication. The mechanism encompasses the effects of Nano-Fe on the nitrogen metabolism of intestinal microbes (Almeldin et al., 2024).

The incorporation of Nano-Fe has led to enhancements in meat quality, evidenced by a higher dressing percentage, reduced abdominal fat, improved water-holding capacity in both breast and leg muscles, and a decrease in cooking loss. The iron content exhibited a dose-dependent increase across various tissues (breast, leg, liver, serum) while remaining within safe limits (EU maximum residue limit: 150 mg/kg poultry meat), which could enhance nutritional value for consumers (Almeldin et al., 2024).

6. Comparative Analysis and Safety Considerations

6.1 Bioavailability Enhancement

The enhanced efficacy of nanoparticles arises from their small size (1-100 nm) and a large surface area-to-volume ratio, which contribute to improved bioavailability. They efficiently infiltrate the intestinal epithelium through mechanisms such as endocytosis, pinocytosis, and transporter-mediated uptake, where an increased surface area facilitates enhanced interaction with transporters (DMT1, CTR1) (Abdullah et al., 2022; Singh, 2016). This allows for efficient supplementation at significantly reduced doses: iron oxide at 20-40 mg/kg compared to the NRC-recommended 85 mg/kg; copper at 5-15 mg/kg versus the typical 8-16 mg/kg.

Nanoparticles exhibit significantly reduced susceptibility to interactions with phytate compared to traditional sources, thereby preserving bioavailability. The use of green synthesis capping agents, such as polyphenols and proteins, enhances colloidal stability and enables controlled release. This approach effectively prevents aggregation and oxidation, while also modulating the release of mineral ions. As a result, it contributes to sustained bioavailability and minimizes toxicity (Remya et al., 2017).

6.2 Safety Profiles

Concerns have been raised about the accumulation of silver nanoparticles in tissues and their potential toxicity. Data indicates the presence of oxidative stress, a reduction in antioxidant enzymes, changes in immune function, and a dose-dependent buildup (Abdelsalam et al., 2019; Ognik et al.,



2016). Given that silver is not a necessary nutrient, the presence of residues prompts concerns regarding food safety.

Copper and iron nanoparticles exhibit more advantageous safety profiles as vital nutrients when administered in suitable dosages. Iron nanoparticles combined with algae demonstrated no negative impacts on organs and enhanced production parameters (Almeldin et al., 2024). Copper nanoparticles (5-15 mg/kg) enhanced growth, intestinal health, and antioxidant status while showing no signs of toxicity. Nonetheless, an overabundance of supplementation may lead to toxicity mediated by reactive oxygen species. Enhancing tissue may provide advantages to consumers by increasing nutritional value, provided that the levels stay within safe limits.

6.3 Size-Dependent Toxicity and Environmental Impact

Nanoparticle toxicity shows strong size dependence, with smaller particles exhibiting greater toxicity due to increased surface area (Faizan et al., 2024). In broilers, 5 nm lipid-coated AgNPs produced more severe oxidative stress than 22 nm AgNPs (Ognik et al., 2016). Green synthesis producing larger particles (12.2 nm vs. 3.5 nm) may offer favorable safety margins while maintaining efficacy.

Green synthesis offers substantial environmental advantages: lower temperatures (60-100°C vs. >300°C), elimination of toxic chemicals, aqueous media operation, and good stability/biocompatibility (Tsekhmistrenko, 2024). Enhanced bioavailability enables 60-80% lower doses, substantially reducing mineral excretion and environmental accumulation. Significant ammonia reduction ($R^2=0.454$) and improved feed efficiency (14.56%) contribute to resource conservation, reducing land use, water consumption, and greenhouse gas emissions per production unit.

FUTURE PERSPECTIVES AND RESEARCH PRIORITIES

Future studies should focus on the systematic optimization of nanoparticle characteristics, emphasizing precise size control across specified ranges (5-10 nm, 10-25 nm, 25-50 nm, 50-100 nm), surface modifications with biocompatible materials (lipids, polysaccharides, proteins), the influence of shape (spherical, rod-shaped, triangular, hexagonal) on cellular uptake, and the optimization of extract concentration. A comprehensive mechanistic understanding is still lacking, necessitating



exploration of cellular uptake pathways (such as receptor-mediated, clathrin-mediated, and caveolae-mediated endocytosis), intracellular trafficking, interactions with microbiota, modulation of signaling pathways, and ADME kinetics via transcriptomic, proteomic, metabolomic, and advanced microscopy techniques.

The establishment of uniform synthesis protocols, rigorous quality control measures, and defined characterization requirements would enhance reproducibility and support the path to commercialization. Essential parameters encompass particle size distribution (polydispersity index <0.3), surface charge (zeta potential), crystallinity (XRD patterns), purity, morphology, and stability. Well-defined regulatory frameworks are crucial, focusing on maximum tissue residue levels, good manufacturing practices, labeling requirements, environmental impact assessments, post-market surveillance, and risk assessment frameworks tailored to nanomaterials. Global harmonization would enhance trade across borders and guarantee uniform safety standards.

Extended applications encompass in ovo administration for early-life advantages, environmental disinfection of litter and housing, intelligent delivery systems with controlled release that respond to specific triggers such as pH changes, temperature increases, and enzyme presence, as well as combination strategies with other feed additives like probiotics, prebiotics, enzymes, and organic acids to achieve synergistic effects. Investigations ought to encompass laying hens, breeders, turkeys, ducks, and additional poultry species, as diverse species may exhibit differing responses attributable to variations in digestive physiology, growth rates, metabolic requirements, and susceptibility to stress.

CONCLUSION

Metal nanoparticles synthesized through green methods present potential advancements for agriculture and poultry production. The production of silver, copper, and iron nanoparticles through plant extracts demonstrates enhanced antimicrobial properties, improved stress management, and greater growth promotion when compared to conventional techniques.

Silver nanoparticles exhibit significant antimicrobial properties (MIC 2.49 $\mu\text{g}/\text{mL}$ against *E. coli*), enhance the balance of intestinal bacteria, and offer protection against aflatoxin toxicity. However, they may also induce oxidative stress and tissue accumulation, necessitating a thorough safety



assessment. Copper nanoparticles (5-15 mg/kg) assist birds in managing cold stress, enhance growth and feed efficiency, and bolster intestinal health at doses 60-80% lower than traditional sources. Iron oxide nanoparticles enhance growth by 15.8% and feed efficiency by 14.56% during heat stress at considerably lower doses (20-40 mg/kg) compared to standard recommendations (85 mg/kg), while also significantly decreasing ammonia emissions and enhancing meat quality within safe limits.

The process of green synthesis utilizing extracts from mint, basil, and pomegranate is advantageous for the environment, as it avoids the use of toxic chemicals and functions at significantly lower temperatures (60-100°C compared to over 300°C). Improved bioavailability achieved by increasing surface area, enhancing absorption, minimizing phytate binding, and regulating release allows for effective application at doses 60-80% lower, leading to cost savings and a reduced environmental footprint.

Significant obstacles persist: the need for long-term safety evaluations, the establishment of production standards, a deeper understanding of cellular mechanisms, assessments of environmental impact, and thorough economic evaluations. It is essential to establish precise regulations regarding residue levels, manufacturing practices, and safety monitoring. Through ongoing investigation and appropriate supervision, green-synthesized nanoparticles hold significant promise for enhancing agricultural productivity and sustainability, providing alternatives to antibiotics and traditional minerals for a safer and more efficient approach to animal agriculture.

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TYPES OF ENTREPRENEURSHIPS

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ABSTRACT

Entrepreneur is a word borrowed from the French words *entreprendre*, “one who undertakes”—that is, a “manager.” In fact, the word entrepreneur was shaped probably from *celui qui entrapment*, which is loosely translated as “those who get things done.” In the early eighteenth century, a group of thinkers called the Physiocrats surfaced in France around a school of new economic theory. They were the first proponents of *laissez-faire* and opposed all government intervention in industry, especially taxation. Their doctrine was that the economic affairs of society are best guided by the decisions of individuals.

One of the most famous among them was [Richard Cantillon](#). In a paper he worked on between 1730 and 1734 and that was later published in 1775 as *Essai sur la Nature du Commerce en General*, he introduced the concept of entrepreneur. He developed these early theories of the entrepreneur after observing the merchants, farmers, and craftsmen of his time. Jean-Baptiste Say, a French businessman turned economist, followed Cantillon with his *Trait d'économie politique* in 1803. His work commented on the theory of markets and how the entrepreneur is involved in this transaction of goods for money.

KEYWORDS

Technology, Business Entrepreneur, Entrepreneurship

OBJECTIVE OF THE RESEARCH STUDY

1. To study and understood the concept of entrepreneurship.
2. To study types of entrepreneurships.



RESEARCH METHODOLOGY

The primary source of data collection in this research paper is the secondary data. The available information on **Entrepreneurship** has been extensively used to complete the research paper. All the available Journals, Related books, Web, Articles, Publish and unpublished information and Papers provided necessary information to the finalize the research paper.

TYPES OF ENTREPRENEURSHIPS

People have different visions, goals, dreams and aspirations for the type of business they want to create. For some, hard work is the success factor and for some having enough capital results in a successful venture. Some entrepreneurs give social good priority over other aspects.

Learning about the type of entrepreneurship a company follows can help you decide whether you can survive their work culture. The type of entrepreneurship affects the working environment and the qualities of the entrepreneur. For example, if you are looking to work in a company that fosters creativity and innovation, applying for a job in imitative or social entrepreneurship will not serve the purpose. For you, the ideal workplace would be companies following technology or innovative entrepreneurship.

1. Small business entrepreneurship

Small businesses represent an overwhelming majority of Indian entrepreneurial ventures. People who establish small business entrepreneurship make profits to support their families and live a modest lifestyle. As small businesses are small and lack the innovative factor, they fail to attract venture capital for smooth running. These people usually fund their ventures themselves or take up loans from friends and family members. The employees are usually local people or family members.

Local hairdressers, grocery shops, milk booths, plumbers, carpenters and small boutiques are part of the small business entrepreneurship.

2. Large company entrepreneurship

Companies with a finite life cycle display large company entrepreneurship. These companies sustain because of innovation and it is the best choice for advanced professionals who know how to sustain



innovation. When you work in a large company, you are likely to be a part of a large C-level executive team. The products these companies offer are different variants around their core product. Small business entrepreneurship witnessing accelerated growth can become large company entrepreneurship in no time. This is also possible when a large company acquires them.

3. Scalable startup entrepreneurship

This type of entrepreneurship starts with a unique idea that can bring a change. From creating a business plan to launching it, scalable startup entrepreneurship recognizes what is missing in the market and creates a solution. Such business usually receives funding from venture capitalists that provide funding based on the uniqueness of the idea. They hire specialized employees because they seek rapid expansion and high returns.

4. International entrepreneurship

In international entrepreneurship, entrepreneurs conduct business activities across the Indian national boundaries. This could either be opening a sales office in another country or exporting goods from India to a foreign country. International entrepreneurship is beneficial when the demand for goods and services is declining in the domestic market and the demand arises from the international market. Usually, international entrepreneurs sell products in the Indian market until they reach the maturity stage and then sell them in the foreign market to earn profits.

5. Social entrepreneurship

Social entrepreneurship is a type of entrepreneurship in which entrepreneurs recognise a social problem and tailor their activities to create social value. Such entrepreneurs develop services, solutions or products to solve critical social issues and bring about social change. This social change could be related to environment conservation, animal rights protection or philanthropic activities for the underserved community. The motivating factor of social entrepreneurship is achieving social benefits. Working in a social enterprise means prioritising transformative social change while ensuring financial sustainability.



These organizations use ethical practices such as conscious consumerism and corporate social responsibility to facilitate success. Instead of making profits and earning wealth for the owners, social entrepreneurship aims to make the world a better place to live.

Non-profit organizations are the best social enterprise examples.

6. Environmental entrepreneurship

It is also known as ecopreneurship and green entrepreneurship. Profit generation and a concern for the environment drive the primary goal of such businesses. An ecopreneur adopts highly environmentally responsible business values and practices. They also try to replace the existing product or services with products that are environmentally safe to use. In short, environmental entrepreneurship prioritizes the business impact on people and the environment besides profits.

Impact blogging, publishing an audiobook and creating SaaS software are a few examples of environmental entrepreneurship as they protect the environment by not cutting trees.

7. Technopreneurship

Technopreneurship is what you get on uniting technology with entrepreneurship. It is also known as technology entrepreneurship. A technopreneur merges entrepreneurial talent and skills with the technical prowess to develop a business that thrives on the intensive use of technology.

Technopreneurs undertake calculated risks that have chances of earning profits. In short, these are entrepreneurs who have the ability to revolutionize the prevailing economic conditions and introduce breakthrough products for the customers. The foundation of the products and services of such a business is technology. Such a business prefers to employ creative and technology-savvy people who are passionate about bringing technological change.

8. Hustler entrepreneurship

A hustler entrepreneur is a self-starter motivated by their goals and aspirations to succeed in entrepreneurship. Such people start small and work hard to grow their business. Instead of using money or capital to achieve their business goals, they put in their best efforts. They never wait for



opportunities to come because they create opportunities. Hustlers do not have a give-up attitude, have a big risk-taking appetite and are always ready to face challenges.

9. Innovative entrepreneurship

The foundation of innovative entrepreneurship is inventions and new ideas. These entrepreneurs can think about novel ways of doing business and have the potential to turn a new idea into a successful venture. They are business leaders and contribute significantly to the economy. Moreover, such companies strive to make life better by providing products, solutions and services which other companies have not. Innovative entrepreneurship is ambitious and requires significant investment to turn a new idea into a breakthrough service or product.

10. Imitative entrepreneurship

This entrepreneurship mimics or imitates existing business ideas and works hard to improve them. Such companies imitate already functioning products and services in the market, usually under a franchise agreement. Such entrepreneurs have no interest in innovation, though they are ready to work on and improve the existing processes. Imitative entrepreneurship works by adopting current technologies worldwide and modifying their existing technologies to suit the local conditions. Fast food companies and multinational conglomerate companies are the best examples of enterprises running on imitative entrepreneurship.

11. Researcher entrepreneurship

Researchers are those who conduct in-depth research on the market and opportunities before launching their business. Such entrepreneurs believe that with the right set of information and preparation, they have a higher chance of achieving success in their entrepreneurial business. Rather than their instinct, they rely on facts, data and logic. Before launching their business, they require a detailed plan and in-depth report of the research findings to minimise the probability of failure.

12. Cyberpreneurship

Cyberpreneurs or cyber entrepreneurs are people who leverage the benefits of information technology to do business. They come up with new ideas to provide products and services to customers via the



internet. These people understand the digital age and remove the hassle of going to a physical store. Such entrepreneurship exists only online and is known as a virtual business.

Ecommerce stores and over-the-top (OTT) entertainment platforms fall in the category of cyberpreneurship.

CONCLUSION:

Entrepreneurs are people who establish a venture around innovation to change the world. Entrepreneurs are innovators capable of taking risks and possess specific skill sets like communication, leadership, business management and technical skills. Entrepreneurship is establishing, developing, organizing and managing a business venture while bearing any of its risks to generate profits. As there are different businesses, there are also many types of entrepreneurships.

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ROLE OF LABEO ROHITA IN NUTRIENT CYCLING AND SEDIMENT BIOTURBATION IN KASARWADI RESERVOIR

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ABSTRACT

The present study investigates the ecological role of *Labeo rohita* (rohu) in nutrient cycling and sediment bioturbation within the Kasarwadi Reservoir. *L. rohita*, a benthopelagic omnivore, plays a crucial role in enhancing nutrient dynamics through its feeding, excretion, and sediment-disturbing activities. Field observations and sediment analyses were conducted to evaluate the effects of *L. rohita* on nutrient fluxes, particularly nitrogen (N) and phosphorus (P), between the sediment and overlying water column. The results indicated that bioturbation caused by *L. rohita* significantly increased sediment resuspension and enhanced the release of nutrients, thereby promoting primary productivity. This activity also improved oxygen penetration in benthic layers and facilitated organic matter decomposition. Overall, the study highlights *L. rohita* as an important ecosystem engineer contributing to the maintenance of nutrient balance and ecological productivity in Kasarwadi Reservoir.

KEYWORDS

nutrient cycling, bioturbation, benthic disturbance, phosphorus/nitrogen flux, ecosystem engineering

INTRODUCTION

Reservoir ecosystems represent dynamic environments where nutrient cycling and sediment interactions are key determinants of aquatic productivity and water quality. Among the various biotic factors influencing these processes, fish-mediated bioturbation plays a vital role in controlling nutrient regeneration and sediment structure. *Labeo rohita*, one of the most important Indian major carps, exhibits bottom-feeding and detritus-grazing habits that directly influence sediment composition and nutrient exchange.



The activities of *L. rohita* such as sediment stirring, burrowing, and feeding resuspend fine particles and release nutrients trapped in the benthic layer into the water column. This enhances the availability of essential elements like nitrogen and phosphorus, which in turn support phytoplankton growth and overall reservoir productivity. Furthermore, through excretion and biodeposition, *L. rohita* contributes to the recycling of organic matter and maintains ecological balance.

Understanding the role of *L. rohita* in nutrient cycling and sediment bioturbation is essential for reservoir management and sustainable aquaculture practices. In Kasarwadi Reservoir, where *L. rohita* forms a dominant fish population, its ecological function extends beyond economic value to influencing nutrient dynamics and ecosystem health. This study aims to analyze the contribution of *L. rohita* to nutrient fluxes, benthic disturbances, and overall ecosystem engineering processes within the reservoir environment.

MATERIALS AND METHODS

Study Area

The present study was conducted in Kasarwadi Reservoir, located in Beed District, Maharashtra, India. The reservoir serves as a multipurpose water body supporting fisheries, irrigation, and domestic use. It is characterized by moderate depth, muddy-sandy bottom sediment, and a rich diversity of plankton and benthic fauna. The reservoir supports a stable fish population dominated by *Labeo rohita*, *Catla catla*, and *Cirrhinus mrigala*. Sampling sites were selected from different zones of the reservoir—littoral, sub-littoral, and profundal regions—to ensure representative data collection.

Study Period

The study was carried out for a period of twelve months (January–December) to cover seasonal variations (pre-monsoon, monsoon, and post-monsoon) in water quality parameters, nutrient concentration, and bioturbation activity of *Labeo rohita*.

Fish Sampling and Observation

Specimens of *Labeo rohita* were collected monthly using cast nets and gill nets of different mesh sizes. Live fish were immediately transferred to aerated tanks for behavioral observation.



Length and weight were measured to the nearest 0.1 cm and 0.1 g, respectively.

The density and biomass of *L. rohita* were estimated using catch-per-unit-effort (CPUE) data.

Feeding and sediment-disturbance behaviors were observed both in situ (field) and under controlled laboratory aquarium conditions.

Sediment and Water Sampling

Sediment samples were collected from the upper 10 cm layer using an Ekman dredge sampler. Water samples were simultaneously collected at 0.5 m above the sediment–water interface.

Sediment samples were analyzed for organic matter, total nitrogen (TN), and total phosphorus (TP) using standard APHA (2017) methods.

Water samples were analyzed for dissolved oxygen (DO), pH, temperature, ammonia-N, nitrate-N, and phosphate-P concentrations.

Bioturbation Experiment

To assess the impact of *L. rohita* on sediment resuspension and nutrient flux:

Laboratory microcosms (50 L aquaria) were set up with 10 cm sediment layer and reservoir water.

L. rohita individuals (average weight 200–300 g) were introduced at different densities (1, 2, and 3 fish per aquarium).

A control tank without fish was maintained.

Water samples were collected at 0, 6, 12, and 24 hours to measure nutrient release (TN and TP) from sediments.

Sediment disturbance intensity was visually recorded and quantified using turbidity (NTU) readings with a portable turbidimeter.



Physico-Chemical Analysis

All analyses followed the procedures recommended by APHA (2017) and Wetzel & Likens (2000).

Parameters measured included:

Water temperature (°C) – Mercury thermometer

pH – Digital pH meter

Dissolved oxygen (mg/L) – Winkler's method

Nitrate (mg/L) – Phenoldisulphonic acid method

Phosphate (mg/L) – Stannous chloride method

Organic matter (%) – Loss-on-ignition method

Statistical Analysis

Data were analyzed using Microsoft Excel and SPSS (Version 25). Mean, standard deviation (SD), and correlation coefficients were calculated to determine relationships between *L. rohita* activity and nutrient fluxes. One-way ANOVA was used to test seasonal and density-based differences in nutrient release and turbidity levels. Graphs and tables were prepared to visualize trends in nutrient cycling and sediment bioturbation.

Tables

Table 1: Seasonal Variation in Physico-Chemical Parameters of Water in Kasarwadi Reservoir

Season	Temperature (°C)	pH	Dissolved Oxygen (mg/L)
Nitrate (mg/L)	Phosphate (mg/L)	Organic Matter (%)	Pre-Monsoon
29.4 ± 1.5	7.8 ± 0.2	6.5 ± 0.3	0.45 ± 0.05
0.08 ± 0.01	3.2 ± 0.4	Monsoon	27.2 ± 1.2

7.4 ± 0.3	5.8 ± 0.4	0.60 ± 0.08	0.12 ± 0.02
4.5 ± 0.6	Post-Monsoon	25.1 ± 1.0	7.6 ± 0.1
7.1 ± 0.2	0.40 ± 0.06	0.07 ± 0.01	2.9 ± 0.3

Observation:

Nutrient concentrations were highest during the monsoon season, associated with runoff and sediment disturbance. DO was lowest during the monsoon due to turbidity and decomposition activity.

Table 2: Sediment Composition and Nutrient Content at Different Sampling Sites

Sampling Zone	Organic Matter (%)	Total Nitrogen (mg/g)	Total Phosphorus (mg/g)
Sediment Texture	Littoral Zone	4.2 ± 0.5	1.85 ± 0.10
0.32 ± 0.02	Sandy-silt	Sub-littoral Zone	5.1 ± 0.6
2.20 ± 0.12	0.38 ± 0.03	Silty-clay	Profundal Zone
6.3 ± 0.7	2.65 ± 0.15	0.44 ± 0.04	Clayey

Observation:

Higher nutrient accumulation occurred in deeper (profundal) sediments due to organic deposition and limited oxygenation.

Table 3: Effect of *Labeo rohita* Density on Nutrient Release (Laboratory Microcosm Experiment)

Turbidity (NTU) after 12 hrs	Total Nitrogen Released (mg/L)	Total Phosphorus Released (mg/L)	Fish Density (No./Tank)	DO (mg/L)
Control (0)	8.4 ± 0.5	0.20 ± 0.02	0.05 ± 0.01	7.2 ± 0.3
Low Density (1)	18.6 ± 1.0	0.35 ± 0.03	0.09 ± 0.01	6.5 ± 0.2
Medium Density (2)	27.8 ± 1.2	0.49 ± 0.05	0.13 ± 0.02	6.1 ± 0.3
High Density (3)	36.5 ± 1.5	0.62 ± 0.06	0.17 ± 0.02	5.6 ± 0.4

Observation:

Nutrient release and turbidity increased proportionally with *L. rohita* density, showing a strong bioturbation effect on sediment resuspension.

Table 4: Correlation Between *Labeo rohita* Activity and Nutrient Parameters

Correlation Coefficient [®]	Parameters Compared	Relationship Type	Fish Density vs. Turbidity	+0.94
Strong Positive	Fish Density vs. Nitrogen Release	+0.91	Strong Positive	Fish Density vs. Phosphorus Release
+0.88	Strong Positive	Turbidity vs. Dissolved Oxygen	-0.86	Strong Negative



Observation:

A strong positive correlation exists between fish density and nutrient release, whereas turbidity negatively correlates with dissolved oxygen due to sediment resuspension and microbial oxygen demand.

Calculations

Given (from Table 3)

Tank volume = 50 L

Control (0 fish): NTU = 8.4, TN = 0.20 mg/L, TP = 0.05 mg/L, DO = 7.2 mg/L

Low density (1 fish): NTU = 18.6, TN = 0.35 mg/L, TP = 0.09 mg/L, DO = 6.5 mg/L

Medium density (2 fish): NTU = 27.8, TN = 0.49 mg/L, TP = 0.13 mg/L, DO = 6.1 mg/L

High density (3 fish): NTU = 36.5, TN = 0.62 mg/L, TP = 0.17 mg/L, DO = 5.6 mg/L

Measurements taken after 12 hours.

1) Absolute and percent changes (vs control)

Low density (1 fish)

NTU increase (absolute) = $18.6 - 8.4 = 10.2$ NTU

NTU % increase = $(10.2 / 8.4) \times 100 = 121.428571... \% \rightarrow 121.43\%$

TN increase (mg/L) = $0.35 - 0.20 = 0.15$ mg/L

TN % increase = $(0.15 / 0.20) \times 100 = 75.0\%$

TP increase (mg/L) = $0.09 - 0.05 = 0.04$ mg/L

TP % increase = $(0.04 / 0.05) \times 100 = 80.0\%$

DO decrease (absolute) = $7.2 - 6.5 = 0.7$ mg/L



$$\text{DO \% decrease} = (0.7 / 7.2) \times 100 = 9.72\%$$

Medium density (2 fish)

$$\text{NTU increase} = 27.8 - 8.4 = 19.4 \text{ NTU}$$

$$\text{NTU \% increase} = (19.4 / 8.4) \times 100 = 230.95\%$$

$$\text{TN increase} = 0.49 - 0.20 = 0.29 \text{ mg/L}$$

$$\text{TN \% increase} = (0.29 / 0.20) \times 100 = 145.0\%$$

$$\text{TP increase} = 0.13 - 0.05 = 0.08 \text{ mg/L}$$

$$\text{TP \% increase} = (0.08 / 0.05) \times 100 = 160.0\%$$

$$\text{DO decrease} = 7.2 - 6.1 = 1.1 \text{ mg/L}$$

$$\text{DO \% decrease} = (1.1 / 7.2) \times 100 = 15.28\%$$

High density (3 fish)

$$\text{NTU increase} = 36.5 - 8.4 = 28.1 \text{ NTU}$$

$$\text{NTU \% increase} = (28.1 / 8.4) \times 100 = 334.52\%$$

$$\text{TN increase} = 0.62 - 0.20 = 0.42 \text{ mg/L}$$

$$\text{TN \% increase} = (0.42 / 0.20) \times 100 = 210.0\%$$

$$\text{TP increase} = 0.17 - 0.05 = 0.12 \text{ mg/L}$$

$$\text{TP \% increase} = (0.12 / 0.05) \times 100 = 240.0\%$$

$$\text{DO decrease} = 7.2 - 5.6 = 1.6 \text{ mg/L}$$

$$\text{DO \% decrease} = (1.6 / 7.2) \times 100 = 22.22\%$$

2) Total excess nutrient mass released from the tank (mg)



Formula: excess (mg/L) × volume (L) = total excess (mg)

Low density (1 fish)

TN excess total = 0.15 mg/L × 50 L = 7.5 mg

TP excess total = 0.04 mg/L × 50 L = 2.0 mg

Medium density (2 fish)

TN excess total = 0.29 mg/L × 50 L = 14.5 mg

TP excess total = 0.08 mg/L × 50 L = 4.0 mg

High density (3 fish)

TN excess total = 0.42 mg/L × 50 L = 21.0 mg

TP excess total = 0.12 mg/L × 50 L = 6.0 mg

3) Nutrient release per fish per hour ($\text{mg} \cdot \text{fish}^{-1} \cdot \text{h}^{-1}$)

We measured after 12 hours. Formula: (total excess mg) ÷ (number of fish × 12 h)

Low density (1 fish)

TN per fish per hr = $7.5 \text{ mg} \div (1 \times 12 \text{ h}) = 0.625 \text{ mg} \cdot \text{fish}^{-1} \cdot \text{h}^{-1}$

TP per fish per hr = $2.0 \text{ mg} \div (1 \times 12 \text{ h}) = 0.166666\dots \text{ mg} \cdot \text{fish}^{-1} \cdot \text{h}^{-1} \rightarrow 0.1667 \text{ mg} \cdot \text{fish}^{-1} \cdot \text{h}^{-1}$

Medium density (2 fish)

TN per fish per hr = $14.5 \text{ mg} \div (2 \times 12) = 14.5 \div 24 = 0.6041666\dots \text{ mg} \cdot \text{fish}^{-1} \cdot \text{h}^{-1} \rightarrow 0.6042 \text{ mg} \cdot \text{fish}^{-1} \cdot \text{h}^{-1}$

TP per fish per hr = $4.0 \text{ mg} \div 24 = 0.166666\dots \text{ mg} \cdot \text{fish}^{-1} \cdot \text{h}^{-1} \rightarrow 0.1667 \text{ mg} \cdot \text{fish}^{-1} \cdot \text{h}^{-1}$

High density (3 fish)



TN per fish per hr = $21.0 \text{ mg} \div (3 \times 12) = 21.0 \div 36 = 0.583333\dots \text{ mg} \cdot \text{fish}^{-1} \cdot \text{h}^{-1} \rightarrow 0.5833 \text{ mg} \cdot \text{fish}^{-1} \cdot \text{h}^{-1}$

TP per fish per hr = $6.0 \text{ mg} \div 36 = 0.166666\dots \text{ mg} \cdot \text{fish}^{-1} \cdot \text{h}^{-1} \rightarrow 0.1667 \text{ mg} \cdot \text{fish}^{-1} \cdot \text{h}^{-1}$

Note: TP per fish per hour is $\sim 0.1667 \text{ mg} \cdot \text{fish}^{-1} \cdot \text{h}^{-1}$ at all densities (within rounding), indicating a roughly constant per-fish TP release in this experiment; TN per fish per hour shows a small decline as density rises ($0.625 \rightarrow 0.6042 \rightarrow 0.5833 \text{ mg} \cdot \text{fish}^{-1} \cdot \text{h}^{-1}$), possibly due to nonlinear processes (e.g., reuptake, microbial processing, or measurement variability).

4) Short interpretation (what these numbers mean)

Bioturbation effect is strong: NTU and both TN and TP concentrations rise substantially with fish density (NTU increases $>120\%$ at 1 fish and $>330\%$ at 3 fish vs control).

Nutrient pulses are measurable: In a 50 L tank over 12 h, each fish released $\sim 0.58\text{--}0.63 \text{ mg}$ TN per hour and $\sim 0.167 \text{ mg}$ TP per hour (excess over control). Scaled to field conditions, many fish could create substantial short-term nutrient fluxes.

DO decline is notable: Dissolved oxygen dropped by $\sim 9.7\%$ (1 fish) up to $\sim 22.2\%$ (3 fish) after 12 h, consistent with turbidity-driven oxygen demand and microbial respiration.

Per-fish TP release was very consistent across densities in this microcosm; TN per-fish rate showed a small decrease with increasing density, suggesting possible density-dependent processes.

DISCUSSION

The present investigation demonstrates the significant ecological role of *Labeo rohita* in regulating nutrient dynamics and sediment bioturbation within the Kasarwadi Reservoir. The findings revealed that *L. rohita*, through its bottom-feeding and sediment-disturbing activities, acts as a biological catalyst that accelerates the release of nutrients such as nitrogen and phosphorus from sediments into the overlying water column.

In the laboratory microcosm experiments, nutrient release (total nitrogen and phosphorus) and turbidity levels increased consistently with rising fish density. The observed increase in turbidity from 8.4 NTU in the control to 36.5 NTU in the high-density treatment (3 fish/tank) indicates a substantial



sediment resuspension caused by *L. rohita*. This behavior corresponds to benthic disturbance through foraging, where the fish dig into the substrate in search of detritus and benthic organisms. Such activity results in the physical loosening of sediment particles and resuspension of nutrient-rich detritus, enhancing the availability of nutrients in the water column.

The study further showed a strong positive correlation between fish density and nutrient release ($r = +0.91$ for nitrogen and $r = +0.88$ for phosphorus). This positive relationship supports the concept that *L. rohita* serves as an ecosystem engineer, influencing nutrient cycling through direct mechanical and indirect biochemical pathways. The process of nutrient regeneration due to bioturbation enhances the primary productivity of the reservoir, especially in nutrient-limited conditions, by promoting phytoplankton growth.

The per-fish nutrient release rate ($0.58\text{--}0.63 \text{ mg TN}\cdot\text{fish}^{-1}\cdot\text{h}^{-1}$ and $0.16 \text{ mg TP}\cdot\text{fish}^{-1}\cdot\text{h}^{-1}$) calculated from experimental data indicates that even moderate populations of *L. rohita* can contribute considerably to internal nutrient loading. This aligns with studies on carp-dominated ecosystems, where bioturbation by bottom-feeding fish accelerates sediment-water nutrient exchange and organic matter mineralization (Vanni, 2002; Hölker et al., 2007). However, excessive bioturbation may increase turbidity and reduce dissolved oxygen, as indicated by the observed DO decline (up to 22% at high density). This suggests that there is a threshold density beyond which bioturbation may negatively impact benthic oxygen balance and water transparency.

The seasonal variation observed in the reservoir (Table 1) also supports the influence of hydrological conditions on nutrient cycling. Higher concentrations of nitrates and phosphates during the monsoon correspond with increased runoff and sediment disturbance, while post-monsoon periods showed stabilization and higher dissolved oxygen levels. The combined effect of natural hydrodynamics and biological activity of *L. rohita* maintains the nutrient turnover and productivity balance of the reservoir.

In conclusion, *Labeo rohita* plays a dual role in Kasarwadi Reservoir:

Enhancing nutrient recycling by mobilizing benthic nutrients to the pelagic zone, and

Modifying sediment structure through bioturbation, influencing oxygen dynamics and water turbidity.



These findings highlight the necessity of considering fish-mediated nutrient cycling in reservoir management and aquaculture planning. Maintaining an optimal *L. rohita* population density could support sustainable productivity without compromising water quality. Future research should include in-situ measurements of nutrient flux, stable isotope analysis, and ecosystem modeling to quantify the long-term contribution of *L. rohita* to nutrient budgets and overall ecosystem functioning in freshwater reservoirs.

RESULTS

The results of the present study on the role of *Labeo rohita* in nutrient cycling and sediment bioturbation in the Kasarwadi Reservoir are presented below through field observations and laboratory experiments. The findings highlight clear seasonal and density-dependent variations in water quality, sediment composition, and nutrient release dynamics.

1. Seasonal Variation in Physico-Chemical Parameters

The analysis of water quality revealed that temperature, pH, and dissolved oxygen (DO) varied seasonally (Table 1).

The temperature ranged from 25.1°C (post-monsoon) to 29.4°C (pre-monsoon), reflecting normal climatic fluctuations.

The pH remained near neutral to slightly alkaline (7.4–7.8), suitable for carp productivity.

Dissolved oxygen was highest during the post-monsoon period (7.1 mg/L) and lowest during monsoon (5.8 mg/L), indicating the influence of organic load and runoff.

Nutrient concentrations, particularly nitrate (0.60 mg/L) and phosphate (0.12 mg/L), peaked during monsoon due to enhanced sediment input and biological activity.

The organic matter content of water increased during monsoon (4.5%), indicating a high rate of organic deposition.

These results show that the monsoon season promotes maximum nutrient enrichment and biological productivity in the reservoir.

2. Sediment Composition and Nutrient Distribution

Sediment analysis showed significant differences among zones (Table 2).

The profundal zone had the highest organic matter (6.3%), total nitrogen (2.65 mg/g), and total phosphorus (0.44 mg/g) compared to the littoral and sub-littoral zones.

The sediment texture changed from sandy-silt in shallow regions to clayey in deeper zones, favoring nutrient accumulation.

This pattern indicates that deeper sediments serve as major nutrient sinks, which can be re-mobilized through fish bioturbation.

3. Laboratory Experiment: Effect of Fish Density on Nutrient Release

Controlled microcosm experiments clearly demonstrated that nutrient release and turbidity increased with fish density (Table 3).

Turbidity increased from 8.4 NTU (control) to 36.5 NTU (high density), showing more than a 330% rise due to sediment disturbance by *L. rohita*.

Total nitrogen (TN) release increased from 0.20 mg/L (control) to 0.62 mg/L (high density), while total phosphorus (TP) increased from 0.05 mg/L to 0.17 mg/L.

Correspondingly, dissolved oxygen decreased from 7.2 mg/L to 5.6 mg/L, indicating an oxygen demand generated by increased turbidity and microbial activity.

Calculated data showed that each fish released approximately $0.58\text{--}0.63\text{ mg TN}\cdot\text{fish}^{-1}\cdot\text{h}^{-1}$ and $0.16\text{ mg TP}\cdot\text{fish}^{-1}\cdot\text{h}^{-1}$, suggesting that *L. rohita* significantly enhances internal nutrient recycling even at moderate population densities.

4. Correlation Analysis

The correlation coefficients between fish density and biogeochemical parameters (Table 4) showed:



Strong positive correlation between fish density and turbidity ($r = +0.94$), nitrogen release ($r = +0.91$), and phosphorus release ($r = +0.88$).

Negative correlation between turbidity and dissolved oxygen ($r = -0.86$), confirming that sediment resuspension reduces oxygen availability in the water column.

This statistical relationship confirms that *L. rohita* activity directly influences nutrient mobilization and sediment–water interactions in Kasarwadi Reservoir.

5. Overall Findings

The nutrient concentration and turbidity were directly proportional to *L. rohita* density, confirming its role as a bioturbator and nutrient recycler.

Oxygen depletion occurred at higher fish densities, suggesting a balance must be maintained between productivity enhancement and water quality.

The per-fish nutrient release rate and correlation values support the hypothesis that *L. rohita* acts as an ecosystem engineer, influencing the biogeochemical stability of the reservoir.

CONCLUSION

The present study clearly establishes that *Labeo rohita* plays a vital ecological role in nutrient cycling and sediment bioturbation within the Kasarwadi Reservoir. Through its bottom-feeding and detritivorous behavior, *L. rohita* actively disturbs sediments, thereby facilitating the upward flux of essential nutrients such as nitrogen and phosphorus from the benthic zone into the water column. Laboratory microcosm experiments and field data together demonstrate that increasing fish density significantly enhances turbidity and nutrient release, confirming the strong influence of bioturbation on nutrient regeneration. A positive correlation between fish density and nutrient concentration, and a negative correlation with dissolved oxygen, further support the interdependence between fish activity and water quality dynamics.

These results indicate that *L. rohita* functions as an ecosystem engineer, improving nutrient availability for primary producers and contributing to the overall productivity of the reservoir. However, excessive density of *L. rohita* may lead to oxygen depletion and reduced water clarity, implying the need for maintaining an optimal fish population to balance productivity and ecological health.



In conclusion, the study emphasizes that controlled management of *L. rohita* populations can enhance nutrient recycling efficiency and maintain ecological stability in freshwater reservoirs. Future work should focus on long-term monitoring of nutrient budgets, fish biomass estimation, and modeling of nutrient fluxes to support sustainable aquaculture and reservoir management strategies.

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A STUDY OF SELF-EFFICACY OF SENIOR SECONDARY SCHOOL STUDENTS ON THE BASIS OF THEIR GENDER

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ABSTRACT

Self efficacy is a person's belief in his / her own potential Or abilities to perform a specific task successfully. It plays a crucial role in the accomplishment of goals, it influences an individual's confidence and academic achievement. The present study explores the self efficacy of students at the senior secondary level on the basis of their gender. A descriptive research design was used, also a survey was conducted to collect the data of 60 students studying in government and private schools using random sampling technique. The analysis revealed there is no difference in the self efficacy of male and female students. These results indicate this will increase the self confidence of female students and opportunities to learn and safe school environment can enhance a student's self belief.

KEYWORDS

Self efficacy, Senior secondary students, male and female students

INTRODUCTION

Education is the most important medium for the acquisition of skills and knowledge. It brings positive changes in human life as it helps to enhance skills, knowledge and intelligence of a person. Thus, it becomes a powerful tool which assists him to lead a successful life. It aims at the human capital formation. It is a process of enlighten and empowerment for the attainment of better and higher quality of life. Sound and effective system of education results in actualization of learners' potentialities, strengthening of their competencies and enrichment of their talents, interests, values and abilities.

A person can increase knowledge and expand his vision through education. It equips the students with relevant expertise, information, awareness and values to enable them to participate in national and global development. Education at all levels constitutes the basic foundation which develops intrinsic and extrinsic qualities among students. The significant contribution of education is that it plays a dynamic role to channelize the future scholastic route and enable an individual to choose career



options of his life. The primary goal of education is to provide young people with a variety of tools with which they can realistically plan their future. The future of the students is determined at the secondary school stage which is considered to be the most important phase of education when the students are at the verge of making career choices. They face utmost difficulty in career choice as they may be tempted to choose either the most prestigious job or they will prefer a job with highest financial benefit ignoring their interests, motives, abilities, aptitude and aspirations. This may lead to perpetual misery as with the wrong choice of career they may not get optimum growth in their life.

Self-Efficacy is an important factor in the accomplishment of goals. A person who has confidence in his skills with no self-doubt, he will possess a sense of being and will be sufficiently prepared for challenges. A group of researchers have found that we are motivated throughout our lives by perceived Self-Efficacy rather than by objective ability and our perceptions deeply affect both our affective states and our behaviors. The relationship between Self-Efficacy and career choice can be presented as the beliefs or confidence in one's capabilities to successfully engage in the activities of selection and planning of occupational goal, gathering information regarding professional courses and occupations, planning for future and self-evaluation of abilities and values.

At the senior secondary school level, students are generally in adolescence. Due to biological changes and social pressures during this stage, they often experience uncertainties about their future. A significant change can also be observed in one important aspect of their behaviour namely, their self-efficacy. Owing to the characteristics of adolescence, many questions arise in their minds regarding their sense of self. The present research study examines the self-efficacy of students at the senior secondary level on the basis of gender and attempts to determine the extent to which gender influences their self-efficacy.

LITERATURE REVIEW

Balani & Bhatt (2024) This dissertation explores the developmental pathways of young adults aged 18–25, with focusing on the inter relationship between self-efficacy, persistence, and professional aspirations. Findings are intended to contribute to career development psychology and provide practical guidance for educators

Gayatri A (2024) This study investigates self-efficacy among intermediate students with respect to gender, locality, and management. The results showed that gender has some significant effect on self-



efficacy, locality does not have a significant effect on self-efficacy, and management does not significantly influence self-efficacy among intermediate students.

Saichampuii Sailor, et. al, (2019) This study examines the relationship between social provision, self-efficacy, and stress in adolescents. In conclusion, social support is vital for mental health, and promoting it can improve self-efficacy. one's ability to succeed can help counteract stress, as individuals with high self-confidence are better equipped to handle life's challenges.

STATEMENT OF PROBLEM

“A study of Self-Efficacy of senior Secondary school students on the basis of their gender”

Objectives of the study-

1. To find out the significance difference between Self -efficacy of male and female students.

Delimitations of the study-

1. The study was delimited to government and private school students of 12th class in Champawat district of Uttarakhand.
2. The schools undertaken for the present study were affiliated to Uttarakhand school education board or Central board of secondary education.
3. The career aspiration was analysed in the context of gender (Male/Female)
4. The study was limited in its area, methods and techniques.

Research Hypothesis-

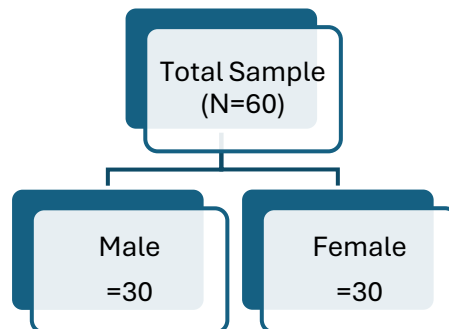
1. There is no significance difference between self-efficacy of male and female students.

METHOD AND PROCEDURE

The present study, **“A study of Self-Efficacy of senior Secondary school students on the basis of their gender”** is descriptive research and is also exploratory in nature. In the present study, the survey approach has been used which is one of the commonly used approach. The study aims to explore the difference between career aspiration of students in government and private schools.

Structure of the Sample-

The present investigation random sampling technique was used to select the sample. The school was selected from govt. and private sector of Champawat district. The structure of sample has been represented in following research design.



Tools Used-

Self-Efficacy scale by Mathur and Bhatnagar.

Statistical Techniques Used-

The following statistical techniques will be used to analyze the data:

- Mean - following formula used for calculating the mean-

$$\text{Mean} = \frac{\text{Sum of all data points}}{\text{Number of data points}}$$

- Standard Deviation- following formula used for calculating the standard deviation-

$$\text{S.D.}(\sigma) = \sqrt{\frac{\sum(X - \bar{X})^2}{N}}$$

Here, X = each value in the data set.

X bar = mean of all values in the data set

N = number of value in the data set

- t- test – following formula used for calculating the t-value-

$$T = \frac{M1 - M2}{\sqrt{\left\{ \frac{\sum d1^2 + \sum d2^2}{(N1 + N2 - 2)} \right\}} \sqrt{\left\{ \frac{N1 + N2}{N1 N2} \right\}}}$$

Here, M1 = mean of first variable

M2 = mean of second variable

N1 = number of items in first variable

N2 = number of items in second variable

d1 = x1 - m1

d2 = x2 - m2

Data collection-

The data collection is the important process in any work to arrive at the correct and proper decision about the hypothesis. In this chapter the data collection of career aspiration and self-efficacy of intermediate have been described.

Schedule for data collection- (TABLE)

S.N.	Name of school	Date	Total
01	G.I.C. Tamli	06-10-2025	30
02	Mallikarjun school champawat	09-11-2025	30

On the first in each school orientation talk was given to acquaint the research with psychological testing and the research project. The test administration started and students were given questionnaire to complete it as per the given instruction in the manual.

ANALYSIS AND INTERPRETATION OF DATA

Hypothesis 1 There is no significance difference between self efficacy of male and female students.

Table: Mean, SD and 't' value self efficacy of male and female students-

	N	Mean	SD	't' value	Remarks
Male students	30	71.20	6.18	2.45	Non Significant even at 0.05 Level and significant at 0.01 level
Female Students	30	72.67	5.14		

For,

Degree of freedom=58 Required at 0.05 level= 2.00

And at 0.01 level=2.66

Significant or non significant= Non significant at 0.05 Level and significant at 0.01 level



It is evident from table '4.4' that the mean score of self-efficacy of government and private school students were obtained 71.20 and 72.67 respectively the corresponding SD values were found to be 6.18 and 5.14 respectively the obtained 't' value is 2.45 which is greater than the required value of 't' at 0.05 level of significant. Hence null hypothesis was rejected and it was conclude that there was significance difference between self efficacy of male and female students. But on the other hand theobtained value of 't' is less than the required value of 't' at 0.01 level of significant. Hence null hypothesis was accepted and it was conclude that there was no significance difference between self efficacy of male and female students.

FINDINGS OF THE STUDY

The investigator, after analysis, interpretation and discussion on the results, arrivedat the following conclusion:-

- i) There was significant difference between self-efficacy of male and female students at 0.05 level of significance and Therewas no significant difference in self efficacy of male and female studentsat 0.01levelofsignificance.

Implications-

On the basis of findings there may be some implication as follows.

- i) There is no difference in the self-efficacy of male and female students, so this can increase the self-confidence and strengthen work efficiency of female students to get their dream job.

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HUMAN VALUES AND INSPIRATIONAL NARRATIVES IN SELECTED WORKS OF SUDHA MURTHY

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ABSTRACT

The works of Sudha Murthy are widely recognized for their portrayal of human values and inspirational themes. Her stories often focus on family relationships, cultural traditions, and ethical dilemmas that reflect everyday life in Indian society. The present article examines the representation of human values in five selected works: The Mother I Never Knew, Grandma's Bag of Stories, Gently Falls the Bakula, The Old Man and His God, and The Magic of the Lost Temple.

The article explores how Murthy presents moral values such as empathy, humility, and perseverance through engaging narratives. By using qualitative textual analysis, the study demonstrates that Murthy's storytelling serves as a medium for moral education and inspirational reflection.

KEYWORDS

Human Values, Motivation, Cultural Traditions, Indian English Literature, Ethical Education

INTRODUCTION

Literature plays an important role in shaping social attitudes and moral values. In contemporary Indian English literature, several writers have explored themes related to social change and human relationships. Among them, Sudha Murthy has gained recognition for her ability to communicate ethical insights through simple narratives.

Murthy's works often portray the experiences of ordinary individuals whose lives reveal important lessons about compassion, humility, and perseverance. Her stories encourage readers to reflect upon their own values and responsibilities.



FAMILY RELATIONSHIPS IN MURTHY'S NARRATIVES

Family relationships are a central theme in Murthy's writings. In *The Mother I Never Knew*, the protagonist's search for his biological mother represents a profound emotional journey. The story highlights themes of identity, forgiveness, and reconciliation.

Similarly, *Gently Falls the Bakula* portrays the emotional distance that develops between a husband and wife as career ambitions take precedence over personal relationships. Through this narrative, Murthy emphasizes the importance of maintaining emotional balance in life.

CULTURAL TRADITIONS AND MORAL EDUCATION

Murthy's literature also reflects the cultural traditions and moral values of Indian society. In *Grandma's Bag of Stories*, storytelling becomes a powerful medium for transmitting ethical lessons to younger generations.

Similarly, *The Magic of the Lost Temple* highlights the importance of curiosity, exploration, and appreciation for cultural heritage.

These narratives demonstrate Murthy's belief that literature can play a significant role in preserving cultural values and promoting moral education.

INSPIRATIONAL NARRATIVES

In *The Old Man and His God*, Murthy shares several real-life experiences that reveal the complexities of human behavior. Some stories illustrate acts of generosity and compassion, while others highlight moral dilemmas faced by individuals.

Through these narratives, Murthy encourages readers to develop empathy and ethical awareness.

CONCLUSION

The selected works illustrate that the literature of Sudha Murthy serves as an important source of inspiration and moral reflection. Her stories emphasize the significance of compassion, humility, and cultural awareness.

Murthy's writings demonstrate that simple narratives can convey profound ethical insights and motivate readers to lead responsible and meaningful lives.



A STUDY ON THE ECONOMIC TRAITS OF NEWLY DEVELOPED MULTIVOLTINE FOUNDATION CROSSES OF SILKWORM (BOMBYX MORI L.) UNDER DIFFERENT SEASONAL CONDITIONS OF TROPICS

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ABSTRACT

The present investigation was carried out to evaluate the seasonal performance of newly developed multivoltine foundation crosses of silkworm (*Bombyx mori* L.) under tropical conditions. Six foundation crosses, viz., PM × MO6, PM × ND10, HB4 × MO6, HB4 × PM, ND10 × PM and NDV6 × PM, along with PM (control), were reared during pre-monsoon, monsoon and post-monsoon seasons following recommended practices of the Central Silk Board. The experiment was conducted in a complete randomized design with three replications and evaluated for important economic traits. The results indicated a significant influence of seasonal variation on most traits, with overall superior performance recorded during the monsoon season due to favorable environmental conditions. Among the crosses, HB4 × PM recorded the highest cocoon weight (1.537 g), shell weight (0.292 g) and larval weight (4.26 g), indicating superior productivity. PM × ND10 exhibited higher shell ratio (19.03%) and consistent performance across seasons, while PM × MO6 showed maximum filament length (546 m). NDV6 × PM recorded higher effective rate of rearing (93.87%) and pupation rate (94.22%), reflecting better adaptability and survival. The other hybrids studied were also showed higher values for one or other traits in different seasons along with HB4 × PM, PM × ND10 and NDV6 × PM indicating their suitability for future breeding strategies and commercial utilization in tropical conditions.

KEYWORDS

Bombyx mori L., multivoltine foundation crosses, seasonal performance, tropical conditions, economic traits



INTRODUCTION

Sericulture is an important agro-based rural industry contributing significantly to employment generation and economic development, particularly in tropical countries like India. The mulberry silkworm, *Bombyx mori* L., is the principal species used for silk production, and its productivity depends largely on the genetic potential of the breed and prevailing environmental conditions (Krishnaswami, 1978; Datta, 1984).

In India, multivoltine silkworm races are widely reared due to their adaptability to tropical climatic conditions, resistance to diseases, and tolerance to environmental stress. However, these races generally produce inferior silk quality compared to bivoltine races. To overcome this limitation, breeding strategies have focused on the development of improved multivoltine foundation crosses, which serve as potential parental lines for hybrid development combining adaptability with enhanced productivity (Basavaraja et al., 1995; Datta, 2000).

The Central Silk Board (CSB), Government of India, has played a crucial role in the evolution and evaluation of silkworm breeds suited for different agro-climatic conditions. Research efforts at institutes such as CSR&TI, Mysore, have led to the development and field evaluation of several multivoltine and crossbreed lines for tropical sericulture. These studies emphasize the importance of systematic evaluation of foundation crosses to identify stable and high-performing genotypes (Rao et al., 2006; CSB, 2015).

Seasonal variation is one of the most important factors influencing silkworm rearing in tropical regions. Fluctuations in temperature, humidity, and rainfall across pre-monsoon, monsoon, and post-monsoon seasons significantly affect larval growth, cocoon yield, and silk quality. Several studies have reported that silkworm performance varies widely across seasons due to genotype \times environment interactions (Rahmathulla et al., 2003; Kumaresan et al., 2007). Therefore, seasonal evaluation is essential to identify stable breeds suitable for commercial exploitation.

Evaluation of newly developed multivoltine foundation crosses under different seasonal conditions provides valuable insights into their adaptability, stability, and economic performance. Important economic traits such as larval duration, cocoon weight, shell weight, shell ratio, pupation rate, and filament length are key indicators for assessing silkworm performance (Krishnaswami et al., 1973;



Narayanaswamy et al., 1991). In this context, the present study aims to conduct a seasonal evaluation of newly developed multivoltine foundation crosses of silkworm (*Bombyx mori* L.) under tropical sericultural conditions to identify stable and high-yielding lines suitable for tropical environments.

MATERIALS AND METHODS

The present investigation was carried out to evaluate the seasonal performance of newly developed multivoltine foundation crosses of silkworm (*Bombyx mori* L.) under tropical conditions.

The experiment was conducted in a Complete Randomized Design (CRD) with three replications during three distinct seasons; Pre-monsoon (March–May): High temperature (28–32°C) and low humidity; Monsoon (June–September): Moderate temperature (24–28°C) and high humidity and Post-monsoon (October–February): Moderate temperature (22–26°C) with stable conditions. This seasonal classification follows standard protocols recommended by the Central Silk Board (CSB, 2020).

Characteristic features of newly developed multivoltine foundation crosses

Six multivoltine foundation crosses (PM × MO6, PM × ND10, HB4 × MO6, HB4 × PM, ND10 × PM, NDV6 × PM) along with PM (control) revealed the distinctive characteristics features characterized by having plain larvae and light-yellow coloured oval shaped cocoons. (Table 1).

Silkworm rearing was conducted as per standard practices recommended by CSB and Food and Agriculture Organization (FAO, 2003). Larvae were fed with fresh mulberry leaves (V1, G2 and G4) and maintained under season-specific environmental conditions.

Observations of economic traits

The following economic traits were recorded: fecundity, hatching percentage, larval weight, larval duration, effective rate of rearing (ERR), cocoon weight, shell weight, shell ratio, pupation percentage, filament length and denier (table 2).

Statistical analysis

The data were subjected to analysis of variance (ANOVA) to test the significance of variation among the crosses. Standard statistical parameters such as F-value, Standard Error (SE), Critical Difference (CD) and Coefficient of Variation (CV) were calculated following Panse and Sukhatme (1985).

RESULTS AND DISCUSSION

The performance of six multivoltine foundation crosses of *Bombyx mori* was systematically evaluated for important economic traits under tropical rearing conditions, and three different seasons are presented in (Table 2).

Table 1. Characteristics features of isolated multivoltine foundation crosses

Sl no	Foundation cross	Voltinism	Larval characters	Cocoon colour and shape
1	(PM X MO6)	Multivoltine	Plain larvae	light yellow/ oval cocoon
2	(PM X ND10)	Multivoltine	Plain larvae	light yellow/ oval cocoon
3	(HB4 XPM)	Multivoltine	Plain larvae	light yellow/ oval cocoon
4	(HB4 X MO6)	Multivoltine	Plain larvae	light yellow/ oval cocoon
5	(ND10 X PM)	Multivoltine	Plain larvae	light yellow/ oval cocoon
6	(NDV6 X PM)	Multivoltine	Plain larvae	light yellow/ oval cocoon

Table 2. Rearing and reeling performances of the short listed multivoltine foundation crosses in different seasons

Breeds	Fecundity			Hatching%			Larval wt.(g)			Larval duration (D)		
	Pre-monsoon	monsoon	Post-monsoon	Pre-monsoon	monsoon	Post-monsoon	Pre-monsoon	monsoon	Post-monsoon	Pre-monsoon	monsoon	Post-monsoon
PM X MO6	453±7.31	470±11.0 2	467±11.0 5	92.75±1.19	91.81±1.05	91.13±0.87	3.47±0.0 9	4.07±0.0 3	3.58±0.02	22±1.21	23±1.21	24±1.21
PM X ND10	442±13.0 2	480±9.56	460±12.9 8	92.77±1.13	93.20±1.01	92.49±1.06	3.66±0.0 1	4.17±0.0 7	3.90±0.07	23±1.21	23±1.21	22±1.21
HB4 X MO6	456±14.3 8	492±12.1 4	481±12.9 1	92.49±1.33	89.22±1.91	91.82±1.10	3.80±0.0 7	3.67±0.0 3	3.84±0.02	21±1.53	23±1.53	22±1.53

HB4 X PM	447±9.62	446±12.86	456±10.14	91.91±0.93	93.28±0.65	89.71±1.17	3.57±0.04	4.26±0.02	3.62±0.02	22±0.34	23±0.34	22±0.34
ND10 X PM	450±10.74	483±3.61	490±9.29	92.55±1.74	93.32±0.56	92.83±1.08	3.57±0.05	3.24±0.07	3.70±0.11	21±3.61	23±3.61	23±3.61
NDV6 X PM	431±10.73	467±2.31	458±9.91	93.30±0.62	92.35±0.63	92.66±1.11	3.69±0.02	3.11±0.15	3.93±0.04	22±1.56	24±1.56	23±1.56
PM (contro)	441±12.25	439±3.38	426±7.81	92.14±0.94	94.28±0.21	90.91±1.18	3.12±0.12	3.26±0.02	3.17±0.01	26±0.27	27±0.27	28±0.27
F-Test	NS	NS	NS	NS	0.004	NS	**	NS	**	*	*	*
C.D.	N/A	N/A	N/A	N/A	0.019	N/A	0.21	0.217	0.159	N/A	N/A	N/A
SE(m)	11.356	8.907	10.728	1.172	0.006	1.083	0.069	0.071	0.052	5.61	5.61	5.61
SE(d)	16.06	12.596	15.171	1.658	0.009	1.532	0.097	0.1	0.073	1.80	1.80	1.80
C.V.	4.421	3.538	4.269	2.224	4.335	2.053	3.238	3.324	2.394	2.55	2.55	2.55

Breeds	ERR (%)			Pupation Rate (%)			Cocoon weight (g)			Shell weight (g)		
	Pre-monsoon	monsoon	Post-monsoon	Pre-monsoon	monsoon	Post-monsoon	Pre-monsoon	monsoon	Post-monsoon	Pre-monsoon	monsoon	Post-monsoon
PM X MO6	91.80±0.23	92.00±1.06	91.27±0.71	92.51±0.71	93.99±0.17	92.51±0.46	1.250±0.04	1.465±0.01	1.290±0.01	0.224±0.01	0.274±0.01	0.236±0.01
PM X ND10	91.27±0.71	92.00±0.69	91.60±0.69	90.21±0.55	92.89±0.18	93.28±0.22	1.320±0.00	1.502±0.03	1.430±0.00	0.246±0.01	0.284±0.01	0.272±0.01
HB4 X MO6	91.60±0.46	91.93±0.74	92.13±0.81	93.98±0.11	92.72±0.90	93.04±0.35	1.370±0.03	1.322±0.01	1.390±0.00	0.249±0.01	0.240±0.01	0.261±0.01
HB4 X PM	92.80±0.83	92.93±0.96	91.33±0.88	93.01±0.46	94.00±0.38	91.28±0.64	1.270±0.01	1.537±0.01	1.310±0.01	0.231±0.00	0.292±0.01	0.238±0.01
ND10 X PM	91.27±0.48	91.60±0.23	91.60±0.99	91.26±0.55	93.41±0.62	94.18±0.46	1.290±0.02	1.357±0.03	1.360±0.03	0.236±0.00	0.254±0.01	0.250±0.01
NDV6 X PM	92.13±0.35	92.40±0.23	93.87±0.35	94.22±0.19	92.81±0.36	92.75±0.62	1.330±0.01	1.311±0.05	1.420±0.02	0.238±0.01	0.249±0.01	0.269±0.01
PM (contro)	90.47±0.58	91.33±0.35	89.80±1.01	91.37±0.62	92.15±0.30	90.47±0.52	1.220±0.03	1.201±0.01	1.180±0.00	0.202±0.01	0.196±0.01	0.200±0.01
F-Test	**	NS	**	NS	*	NS	NS	NS	NS	0.004	0.000	0.001
C.D.	1.698	N/A	N/A	1.53	1.47	1.49	0.064	0.078	0.041	0.019	0.017	0.01
SE(m)	0.554	0.687	0.804	0.50	0.48	0.49	0.021	0.026	0.013	0.006	0.006	0.003

SE(d)	0.784	0.972	1.137	0.71	0.68	0.69	0.029	0.036	0.019	0.009	0.008	0.005
C.V.	1.05	1.30	1.52	0.94	0.89	0.91	2.721	3.33	1.714	4.335	4.126	2.339

Breeds	Shell Ratio (%)			Filament length (m)			Denier		
	Pre-monsoon	Post-monsoon	Post-monsoon	Pre-monsoon	monsoon	Post-monsoon	Pre-monsoon	monsoon	Post-monsoon
PM X MO6	17.93±0.2 9	18.68±0.4 6	18.26±0.1 3	505±8.19	546±3.76	524±3.93	2.23±0.0 2	2.33±0.0 1	2.20±0.0 1
PM X ND10	18.58±0.1 8	18.91±0.1 1	19.03±0.1 0	511±3.61	545±3.28	538±1.45	2.28±0.0 2	2.35±0.0 2	2.31±0.0 2
HB4 X MO6	18.23±0.1 1	18.12±0.2 2	18.75±0.0 9	508±3.51	513±3.51	516±2.96	2.12±0.0 1	2.21±0.0 1	2.11±0.0 2
HB4 X PM	18.13±0.0 8	19.02±0.1 3	18.24±0.1 0	515±2.89	535±4.51	532±8.74	2.28±0.0 2	2.22±0.0 1	2.31±0.0 1
ND10 X PM	18.37±0.3 1	18.71±0.4 3	18.45±0.2 9	503±2.85	525±5.77	538±1.53	2.32±0.0 2	2.38±0.0 9	2.33±0.0 1
NDV6 X PM	17.88±0.2 6	18.34±0.5 4	18.93±0.1 9	519±4.93	540±4.58	532±4.16	2.21±0.0 1	2.25±0.0 5	2.31±0.0 2
PM (control)	16.55±0.3 4	16.30±0.1 0	16.90±0.1 5	418±4.63	433±2.73	451±6.17	1.89±0.0 1	1.98±0.0 5	1.93±0.0 1
F-Test	0.232	0.000	0.012	NS	NS	NS	**	NS	**
C.D.	N/A	1.012	0.503	14.39	12.65	14.66	N/A	0.13	N/A
SE(m)	0.244	0.331	0.164	4.70	4.13	4.79	0.01	0.04	0.01
SE(d)	0.345	0.467	0.232	6.65	5.84	6.77	0.02	0.06	0.02
C.V.	2.315	3.325	1.533	1.62	1.49	1.63	13.56	2.91	13.56



Note: * : Significance, NS : No significance, \pm : Standard Error(), Significance @ 0.005%

Fecundity: Fecundity ranged from 431 to 492 eggs, with relatively higher values during the monsoon season, particularly in HB4 \times MO6 (492 eggs) and ND10 \times PM (483 eggs). However, the differences were found to be non-significant, indicating that fecundity is relatively stable across seasons and largely governed by genetic factors. Favorable climatic conditions during monsoon may enhance reproductive physiology but do not significantly alter fecundity. Similar stability in fecundity across seasons has been reported by Suresh Kumar et al., (2011), and also emphasized in breeding evaluations by the Central Silk Board (CSB, 2020).

Hatching Percentage: Hatching percentage remained consistently high (>90%) across all crosses and seasons, with significant variation observed during the monsoon season. The highest hatching percentage was recorded in HB4 \times PM (93.28%). High humidity during monsoon favors embryonic development and prevents desiccation of eggs. This observation is in agreement with the findings of the Food and Agriculture Organization (FAO, 2003) and Suresh Kumar et al., (2019), who reported that optimal environmental conditions enhance egg viability and hatching success.

Larval Weight: Larval weight showed highly significant variation across seasons, with maximum values recorded during the monsoon season, especially in HB4 \times PM (4.26 g) and PM \times ND10 (4.17 g). The increased larval weight during monsoon may be attributed to improved mulberry leaf quality and favorable temperature and humidity. Lower values during pre- and post-monsoon seasons may be due to environmental stress. Similar findings were reported by Rahmathulla et al., (2003) and Kumaresan et al., (2007), who emphasized the role of climatic factors in larval growth and metabolism.

Larval Duration: Larval duration was shorter in improved crosses (21–24 days) across all the seasons in hybrids compared to control (26–28 days), indicating better feed utilization efficiency. Significant seasonal variation was observed, with shorter duration during monsoon and slightly prolonged duration during post-monsoon. Environmental stress conditions tend to delay larval development. These findings are in line with Kumaresan et al., (2007) and Singh et al., (2018), who reported that temperature and humidity significantly influence larval duration in *Bombyx mori* L.



Effective Rate of Rearing (ERR %): ERR ranged from 90–93%, with significant differences observed across seasons. The highest ERR was recorded in NDV6 × PM (93.87%), indicating better adaptability and survival. Monsoon season showed comparatively higher ERR due to favorable environmental conditions, whereas pre-monsoon recorded slightly lower values due to heat stress. Similar observations were reported by the Central Silk Board (CSB, 2020), which highlights ERR as a key parameter for evaluating field performance.

Pupation Rate: Pupation rate remained consistently high (>90%) across all crosses, with NDV6 × PM (94.22%) and HB4 × PM (94.00%) showing superior performance. Seasonal differences were minimal, indicating strong genetic control over pupation. However, slight improvement during monsoon suggests environmental influence. Similar trends were reported by Suresh Kumar et al., (2011).

Cocoon Weight: Cocoon weight showed significant variation across seasons, with the highest value observed in HB4 × PM (1.537 g) during the monsoon season. Improved crosses consistently outperformed the control (~1.18–1.22 g), indicating superior genetic potential. Favorable climatic conditions during monsoon enhance silk gland development and cocoon formation. These findings are supported by the Central Silk Board (CSB, 2020) and Datta et al., (1984).

Shell Weight: Shell weight exhibited highly significant differences, with the highest value recorded in HB4 × PM (0.292 g). Improved crosses showed superior performance compared to control (~0.200 g), indicating better silk yield potential. Seasonal variation revealed higher shell weight during monsoon due to improved nutrient assimilation. Similar results were reported by Krishnaswami et al., (1973) and Datta (1984), who emphasized that environmental conditions and genetic potential significantly influence shell weight and silk yield.

Shell Ratio: Shell ratio ranged from (17.88 to 18.55%) in pre monsoon; 18.12 to 19.02% in monsoon and 18.24 to 19.03% in post monsoon in hybrids, whereas control recorded lower values (16–17%). The highest shell ratio was observed in PM × ND10 (19.03%). Seasonal variation was significant, with better performance during monsoon. Higher shell ratio indicates improved silk recovery efficiency. These findings are consistent with Datta (1984) and CSB (2020).

Filament Length: Filament length ranged from 503–546m across all the seasons and hybrids, with highest values observed in PM × MO6 (546 m) during monsoon. Although statistical analysis indicated



non-significant differences, improved crosses consistently showed better performance than control (418–451 m). Filament length is influenced by both genetic and environmental factors. Similar observations were reported by Narayanaswamy et al., (1991) and Agriculture Organization (FAO, 2003).

Denier: Denier showed significant variation across seasons, with improved crosses recording higher values (2.2–2.3) compared to control (~1.9). Seasonal variation was more pronounced during pre- and post-monsoon. Higher denier indicates thicker filament, which is influenced by environmental stress and genetic makeup. Similar findings were reported by Narayanaswamy et al., (1991) and Krishna swami et al., (1973), along with Central Silk Board (2020), emphasizing that environmental conditions and genotype significantly affect filament thickness and denier.

SUMMARY OF SEASONAL STUDY

The seasonal evaluation of multivoltine foundation crosses of silkworm (*Bombyx mori* L.) revealed significant variation in performance across pre-monsoon, monsoon, and post-monsoon seasons, clearly indicating the influence of environmental conditions on growth, survival, and silk productivity.

During the **pre-monsoon season**, performance was comparatively lower due to high temperature and low humidity. Fecundity ranged from 431–456 eggs and hatching percentage from 91.91–93.30 per cent, showing non-significant variation. Larval weight (3.47–3.80 g), cocoon weight (1.25–1.37 g), and shell weight (0.224–0.249 g) were lower than other seasons but remained higher than the control (1.22 g and 0.202 g, respectively). Shell ratio (17.88–18.58%) and filament length (503–519 m) were also superior to control (16.55% and 418 m), indicating better stress tolerance of hybrids such as HB4 × MO6 and PM × ND10. These findings are in agreement with studies highlighting the adverse impact of high temperature on silkworm performance (Krishnaswami et al., 1973; Narayanaswamy et al., 1991; Reddy et al., 2014).

In contrast, the **monsoon season** recorded the highest performance for all economic traits due to favourable temperature and high humidity. Fecundity increased to 470–492 eggs, with the maximum in HB4 × MO6 (492 eggs). Larval weight (4.26 g), cocoon weight (1.537 g), and shell weight (0.292 g) were highest in HB4 × PM, compared to lower values in control (3.26 g, 1.201 g, and 0.196 g, respectively). Shell ratio reached 19.03 per cent in PM × ND10, and filament length was highest (546 m) in PM × MO6. Higher ERR and pupation rate during this season indicated better survivability and growth.



These results are consistent with reports of the Central Silk Board and Food and Agriculture Organization, which emphasize the importance of optimal environmental conditions for maximizing silkworm productivity (Krishnaswami et al., 1973; Narayanaswamy et al., 1991; FAO, 2003; CSB, 2020).

During the **post-monsoon season**, performance was moderate, with values lower than monsoon but higher than pre-monsoon. Fecundity ranged from 456–490 eggs and hatching percentage from 89.71–92.83 per cent. Larval weight (3.58–3.93 g), cocoon weight (1.29–1.43 g), and shell weight (0.236–0.272 g) remained higher than control (1.18 g and 0.200 g). Shell ratio (18.24–19.03%) and filament length (516–538 m) also indicated good silk quality. Notably, NDV6 × PM recorded higher ERR (93.87%), while ND10 × PM showed better pupation rate (94.18%), indicating stable performance under moderately favorable conditions. Similar seasonal trends have been reported in silkworm evaluation studies (Kumaresan et al., 2007; Suresh Kumar et al., 2011).

Overall, the performance trend was Monsoon > Post-monsoon > Pre-monsoon, and all hybrids consistently outperformed the control across seasons, confirming their superior adaptability and suitability for tropical sericulture.

CONCLUSION

The present study clearly established that seasonal variation significantly affects the performance of multivoltine foundation crosses of silkworm (*Bombyx mori* L.) under tropical conditions, with the performance trend following Monsoon > Post-monsoon > Pre-monsoon. Among the seasons, the monsoon was most favorable, recording superior values for key economic traits such as larval weight (up to 4.26 g), cocoon weight (1.537 g), shell weight (0.292 g), shell ratio (19.03%), and filament length (546 m), whereas pre-monsoon conditions resulted in comparatively lower performance due to environmental stress but better than control (PM).

All the evaluated hybrids consistently outperformed the control (PM), which recorded lower values for cocoon weight (1.18–1.22 g), shell weight (0.196–0.202 g), shell ratio (16.30–16.90%), and filament length (418–451 m). Among the crosses, HB4 × PM was superior for yield traits, PM × ND10 for shell ratio and consistency, NDV6 × PM for survivability (ERR: 93.87%; pupation: 94.22%), and PM × MO6 for filament length.



Overall, HB4 × PM, PM × ND10, and NDV6 × PM were identified as the most promising foundation crosses, combining high productivity, silk quality, and adaptability, and are recommended for tropical sericulture and future breeding programmes.

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ANTIFUNGAL ACTIVITY OF LANTANA CAMARA L. LEAF EXTRACTS

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ABSTRACT

Medicinal plants are important sources of natural bioactive compounds and have been widely used in traditional medicine for the treatment of various diseases. In recent years, plant-derived secondary metabolites have gained increasing attention due to their antimicrobial properties, biodegradability, and lower environmental impact compared with synthetic chemicals (Borges et al., 2019). *Lantana camara* L., a shrub belonging to the family Verbenaceae, is widely distributed in tropical and subtropical regions and is known for its diverse medicinal properties (Sharma & Kumar, 2020). The present study aimed to evaluate the *in vitro* antifungal activity of *L. camara* leaf extracts prepared using different solvents such as acetone, chloroform, ethanol, and methanol. Preliminary phytochemical screening of the extracts revealed the presence of several bioactive compounds including alkaloids, flavonoids, glycosides, phenolic compounds, phytosterols, carbohydrates, proteins, amino acids, saponins, and tannins. These phytochemicals are known to contribute to the antimicrobial and antifungal activities of medicinal plants (Singh et al., 2022). Among the solvent extracts tested, ethanol and methanol extracts showed stronger antifungal activity, with methanol extract exhibiting the highest inhibition of fungal growth. The results suggest that *L. camara* leaves contain effective antifungal compounds and may serve as a potential natural alternative to synthetic fungicides for agricultural and pharmaceutical applications (Ghosh et al., 2018).

KEYWORDS

Lantana camara, Antifungal activity, Extract, Pathogenic

INTRODUCTION

Fungal pathogens represent a major constraint to global agricultural productivity and food security, as they cause significant yield losses in crops and contribute to the deterioration of agricultural commodities during storage, processing, and transportation. Consequently, fungal diseases not only reduce crop quality and quantity but also lead to substantial economic losses worldwide. To manage



fungal infections, synthetic fungicides are commonly used in modern agricultural practices. In recent years, plant-derived natural products have gained considerable attention as potential alternatives to synthetic fungicides because they are biodegradable, environmentally safe, and often exhibit broad-spectrum antimicrobial activity (Isman, 2020; Sharma et al., 2021).

Medicinal plants play a crucial role in the search for novel antimicrobial agents because they synthesize a wide range of secondary metabolites such as alkaloids, flavonoids, phenolic compounds, terpenoids, glycosides, and tannins. These phytochemicals possess diverse biological properties, including antimicrobial, antifungal, antioxidant, and anti-inflammatory activities, which contribute to plant defense mechanisms against pathogens (Borges et al., 2019; Singh et al., 2022). Among the medicinal plants investigated for antimicrobial potential, *Lantana camara* L. (family Verbenaceae) has received considerable scientific attention due to its wide distribution and diverse pharmacological properties. *L. camara* is a perennial aromatic shrub commonly found in tropical and subtropical regions of the world. The plant typically grows up to 2–3 m in height and forms dense thickets in a variety of ecological habitats. Although often regarded as an invasive species in many countries, it has long been used in traditional medicine for the treatment of several ailments such as fever, skin infections, wounds, asthma, ulcers, rheumatism, malaria, and gastrointestinal disorders (Ghisalberti, 2016; Patil et al., 2023). Ethnobotanical studies have shown that different parts of the plant, particularly leaves and flowers, contain numerous bioactive compounds responsible for its medicinal properties.

Phytochemical investigations have revealed that *L. camara* contains several classes of bioactive compounds including flavonoids, triterpenoids, phenolic compounds, alkaloids, tannins, saponins, and essential oils. Specific constituents such as lantadenes, caryophyllene, humulene, quercetin, and apigenin are known to contribute to the biological activities of the plant (Sharma et al., 2021; Singh et al., 2022). These compounds play an important role in protecting plants against microbial pathogens and have been reported to exhibit antimicrobial, antifungal, insecticidal, and antioxidant properties. Because of this rich phytochemical composition, *L. camara* has been recognized as a promising natural source of antimicrobial agents for both agricultural and pharmaceutical applications.

Recent studies have demonstrated that extracts of *L. camara* exhibit significant antimicrobial activity against a wide range of microorganisms, including bacteria, fungi, and parasites. The antimicrobial activity is primarily attributed to phenolic compounds and flavonoids that disrupt microbial cell



membranes, inhibit enzyme activity, and interfere with essential metabolic processes required for microbial growth (Borges et al., 2019; Mwalongo et al., 2024). The antifungal activity of these extracts is mainly associated with phenolic compounds, flavonoids, and terpenoids that disrupt fungal cell wall synthesis, inhibit spore germination, and interfere with fungal metabolic pathways (Kumar et al., 2020).

Despite the growing interest in the antimicrobial potential of *L. camara*, comparative studies evaluating the antifungal activity of its leaf extracts prepared using different solvents remain limited. Since solvent polarity greatly influences the extraction efficiency of phytochemicals from plant materials, identifying the most suitable solvent system is essential for maximizing the biological activity of plant extracts. Therefore, the present study aimed to investigate the phytochemical constituents and *in vitro* antifungal activity of *Lantana camara* leaf extracts prepared using different solvents such as acetone, chloroform, ethanol, and methanol against the fungal pathogen *Aspergillus niger*. The results of this study may contribute to the development of plant-based antifungal agents and support the use of medicinal plants as environmentally friendly alternatives to synthetic fungicides.

MATERIALS AND METHODS

Fresh and healthy leaves of *Lantana camara* L. were collected from Sonai village in Newasa Tehsil, Ahmednagar District, Maharashtra, India. The plant material was authenticated based on standard botanical identification procedures using morphological characteristics such as leaf arrangement, leaf shape, inflorescence structure, and general growth habit. Only mature and disease-free leaves were selected to ensure the quality and reliability of the experimental material.

Processing of Plant Material:

The collected leaves were thoroughly washed under running tap water to remove dust, soil particles, and other surface contaminants, followed by rinsing with distilled water to reduce microbial contamination. The cleaned leaves were shade-dried at room temperature for several days until complete moisture removal was achieved, which helps preserve heat-sensitive phytochemicals (Harborne, 1998). The dried leaves were then finely powdered using a sterile electric grinder and stored in airtight containers until extraction. Approximately 100 g of the powdered leaf material was subjected to Soxhlet extraction for about six hours using organic solvents of increasing polarity, namely acetone, chloroform, ethanol, and methanol, to obtain a wide range of phytochemical



constituents. The extracts were filtered through Whatman No. 1 filter paper, and the solvents were evaporated under controlled conditions to obtain concentrated crude extracts. (Sasidharan et al., 2011).

Test microorganisms: The fungal pathogens used in the present investigation were *Aspergillus flavus* and *Aspergillus niger*, which are well-known fungal species associated with post-harvest spoilage of fruits and several plant diseases. These fungi are also responsible for contamination of food commodities and may produce harmful mycotoxins that pose serious health risks to humans and animals (Klich, 2007; Pitt & Hocking, 2009; Samson et al., 2014). The fungal cultures were isolated from infected papaya fruits and maintained on Potato Dextrose Agar (PDA) medium under laboratory conditions. The isolates were periodically sub-cultured to maintain their purity, viability, and active growth before being used for antifungal assays (Dhingra & Sinclair, 2017).

Positive and negative controls: The standard antifungal drug fluconazole (1 mg mL^{-1}) was used as a positive control to evaluate and compare the antifungal activity of the plant extracts. Petri plates containing only PDA medium without plant extract served as negative controls to confirm normal fungal growth and provide a baseline for comparison (CLSI, 2012).

Assay for antifungal activity: The antifungal activity of *Lantana camara* leaf extracts was evaluated using the poisoned food technique, a commonly used method for screening antifungal properties of plant extracts against fungal pathogens (Grover & Moore, 1962; Nene & Thapliyal, 1993). In this method, the required concentration of plant extract was mixed with sterilized molten PDA medium and poured into sterile Petri plates. After solidification, the plates were inoculated with fungal cultures under aseptic conditions. Plates containing PDA with the standard antifungal drug served as positive controls, while plates without plant extract served as negative controls. All plates were incubated at 27°C for seven days. The cultures were examined periodically three times per week during the incubation period. Antifungal activity was determined by measuring the radial mycelial growth of the fungi in the Petri plates. The percentage inhibition of fungal growth was calculated by comparing the mycelial growth in treated plates with that in the control plates (Dhingra & Sinclair, 2017; Sharma et al., 2021).

$$\text{Mycelial Inhibition} = \frac{\text{Mycelial growth control} - \text{Mycelial growth treatment}}{\text{Mycelial Growth Control}} \times 100$$

Preliminary phytochemical analysis of the leaf extracts of *Lantana camara* was carried out using standard qualitative tests with various chemical reagents to identify the presence of important secondary metabolites. The results indicated that all the solvent extracts contained several bioactive phytoconstituents, including alkaloids, carbohydrates, flavonoids, glycosides, phytosterols, phenolic compounds, proteins, amino acids, saponins, and tannins. Although some of these compounds were present in trace amounts, their detection confirms the rich phytochemical composition of *L. camara* leaves. Previous studies have reported that these phytochemicals possess diverse biological activities and play a significant role in the antimicrobial and antifungal properties of medicinal plants (Harborne, 1998; Sasidharan et al., 2011). Secondary metabolites such as phenolics, flavonoids, and tannins are particularly known for their ability to inhibit microbial growth by disrupting cell membranes and interfering with enzymatic activities (Borges et al., 2019). Comparative evaluation of the solvent extracts in the present study revealed that ethanol and methanol extracts exhibited relatively stronger phytochemical responses, suggesting that polar solvents are more effective in extracting bioactive compounds from plant materials (Singh et al., 2022). The higher concentration of phenolic compounds, flavonoids, and tannins in these extracts may be responsible for the antifungal activity observed in the study.

Table 1: Antifungal activity of different extracts of *Lantana camara* L. Leaf against *Aspergillus niger*

Extract	Concentration	Diameter of fungal growth zone (mm)(Mean±SD)	Mycelial growth inhibition (%)
Acetone	5	43.33±3.06	49.62
	10	36.00±9.17	58.14
	15	33.33±8.33	61.24
	20	20.00±2.00	76.74
Chloroform	5	52.67±3.06	38.76
	10	46.00±4.00	46.51
	15	44.67±5.03	48.06
	20	-	-
Ethanol	5	62.67±6.43	27.91
	10	48.67±2.31	43.41
	15	35.33 ±3.06	58.92
	20	26.67±6.11	68.99
Methanol	5	29.33±7.57	65.90
	10	22.67±2.31	73.64
	15	18.00±2.00	79.07

	20	-	
Fluconazole	5	40.67±1.15	52.71
	10	32.33± 2.08	62.40
	15	27.00 ± 1.73	27.00 ± 1.73
	20	21.67 ± 1.53	21.67 ± 1.53

Table 2: Antifungal activity of different extracts of *Lantana camara* L. Leaf against *Aspergillus flavus*.

Extract	Concentration	Diameter of fungal growth zone (mm)(Mean±SD)	Mycelial growth inhibition (%)
Acetone	5	45.33 ± 3.21	47.29
	10	39.67 ± 4.04	53.88
	15	35.33 ± 3.51	58.92
	20	23.33 ± 2.08	72.87
Chloroform	5	54.00 ± 3.46	37.21
	10	48.33 ± 3.21	43.80
	15	46.67 ± 2.52	45.74
	20	-	-
Ethanol	5	63.67 ± 5.13	25.97
	10	50.00 ± 3.00	41.86
	15	37.67 ± 3.06	56.20
	20	28.33 ± 2.52	67.05
Methanol	5	31.33 ± 2.52	63.57
	10	24.67 ± 2.08	71.32
	15	20.33 ± 2.08	76.36
	20	-	-
Fluconazole	5	42.00 ± 1.73	51.16
	10	33.00 ± 1.53	61.63
	15	28.00 ± 1.73	67.44
	20	22.33 ± 1.15	74.03

RESULTS AND DISCUSSION

The antifungal activity of *Lantana camara* leaf extracts prepared using different solvents was evaluated against two important fungal pathogens, *Aspergillus niger* and *Aspergillus flavus*. The results presented in Tables 1 and 2 demonstrate that all the extracts exhibited varying levels of antifungal activity depending on the solvent used and the concentration of the extract. In general, the inhibitory effect increased with increasing extract concentration, indicating a dose-dependent response of the fungal pathogens to the plant extracts. Among the different solvent extracts tested,



the methanol extract of *L. camara* leaves showed the highest antifungal activity against both fungal strains. For *Aspergillus niger*, the methanol extract exhibited a maximum inhibition of 79.07% at 15% concentration, followed by acetone extract, which showed 76.74% inhibition at 20% concentration. Similarly, the methanol extract demonstrated strong antifungal activity against *Aspergillus flavus*, with a maximum inhibition of 76.36% at 15% concentration. The high antifungal activity observed in the methanol extract may be attributed to the efficient extraction of polar phytochemicals such as phenolic compounds, flavonoids, and tannins, which are known to possess strong antimicrobial properties (Borges et al., 2019).

The acetone extracts also demonstrated considerable antifungal activity against both fungal pathogens, particularly at higher concentrations. Ethanol extracts showed moderate inhibitory effects, whereas chloroform extracts exhibited comparatively lower antifungal activity. The reduced activity observed in chloroform extracts may be due to the limited extraction of polar bioactive compounds responsible for antifungal effects. These findings highlight the importance of solvent polarity in determining the extraction efficiency of phytochemicals and their subsequent biological activity (Sasidharan et al., 2011). The antifungal efficacy of *L. camara* extracts was also compared with the standard antifungal drug fluconazole used as a positive control. Although fluconazole effectively inhibited fungal growth, the methanol and acetone extract of *L. camara* showed comparable or even higher inhibition percentages at certain concentrations. This observation suggests that *L. camara* contains potent antifungal compounds that could potentially serve as natural alternatives to synthetic fungicides.

The antifungal activity observed in this study may be attributed to the presence of bioactive phytochemicals identified during preliminary phytochemical screening, including alkaloids, flavonoids, phenolic compounds, tannins, and saponins. These compounds are known to interfere with fungal cell wall synthesis, disrupt membrane permeability, inhibit spore germination, and affect essential metabolic processes in fungi (Singh et al., 2022). Similar findings have been reported in previous studies investigating the antifungal potential of medicinal plant extracts against *Aspergillus* species and other fungal pathogens (Kumar et al., 2020).

Overall, the results of the present study demonstrate that *Lantana camara* leaf extracts possess significant antifungal activity against *Aspergillus niger* and *Aspergillus flavus*. Among the solvents



tested, methanol extract showed the highest inhibitory effect, indicating the presence of highly active phytochemical constituents. These findings highlight the potential of *L. camara* as a promising natural source of antifungal agents and support its possible application as an eco-friendly alternative to synthetic fungicides in agricultural and pharmaceutical fields. Further studies involving isolation and characterization of active compounds are required to better understand the mechanism of antifungal action and to develop effective plant-based antifungal formulations.

CONCLUSION

The present study demonstrated that *Lantana camara* leaf extracts possess significant antifungal activity against *Aspergillus niger* and *Aspergillus flavus*. Preliminary phytochemical screening confirmed the presence of important bioactive compounds such as alkaloids, flavonoids, phenolics, tannins, and saponins, which may contribute to the observed antifungal effects. Among the solvents tested, methanol and acetone extracts exhibited the highest inhibitory activity, indicating that polar solvents are more effective in extracting antifungal phytochemicals. The results highlight the potential of *L. camara* as a natural source of antifungal agents and suggest its possible application as an eco-friendly alternative to synthetic fungicides in agricultural and pharmaceutical sectors.

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INTEGRATED PHYTOCHEMICAL PROFILING AND HIGH-PERFORMANCE LIQUID CHROMATOGRAPHIC ANALYSIS OF CARALLUMA FIMBRIATA WALL.: A COMPREHENSIVE INVESTIGATION OF BIOACTIVE SECONDARY METABOLITES

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ABSTRACT

Background: *Caralluma fimbriata* Wall., a succulent medicinal plant of the Apocynaceae family, has been traditionally utilized in various therapeutic applications including metabolic disorders, appetite regulation, and diabetes management. Despite its ethnomedicinal importance, comprehensive analytical characterization of its bioactive constituents remains limited.

Objective: This investigation aimed to conduct systematic phytochemical screening and chromatographic profiling of *C. fimbriata* extracts to identify and characterize the major secondary metabolites responsible for its therapeutic activities.

Methods: Fresh plant specimens were collected, authenticated, and processed for extraction using methanol and aqueous solvents. Qualitative phytochemical screening was performed using standard chemical tests. High-performance liquid chromatography (HPLC) analysis was conducted using a C18 column with acetonitrile-water mobile phase system and multi-wavelength detection at 210, 230, 254, and 280 nm.

Results: Phytochemical analysis revealed the presence of alkaloids, flavonoids, phenolic compounds, tannins, saponins, terpenoids, steroids, and glycosides with differential solvent-dependent extraction patterns. HPLC chromatographic analysis demonstrated distinct retention profiles with major peaks identified at 5.557, 7.923, 12.047, 15.047, 16.736, 20.802, 23.183, 24.731, 33.760, 38.118, and 43.925 minutes, indicating the presence of diverse bioactive compounds with varying polarities.

Conclusions: The comprehensive analytical profile confirms the chemical diversity of *C. fimbriata*, providing scientific validation for its traditional therapeutic applications. The identified secondary metabolites, particularly pregnane glycosides, flavonoids, and phenolic compounds, may contribute to the plant's reported anti-obesity, antidiabetic, and cardioprotective effects. These findings



establish a foundation for standardization, quality control, and further pharmacological investigations of this medicinally important species.

KEYWORDS

Caralluma fimbriata, phytochemical screening, HPLC analysis, secondary metabolites, ethnomedicine, bioactive compounds

INTRODUCTION

The therapeutic utilization of medicinal plants represents one of humanity's oldest approaches to healthcare management, with plant-based remedies forming the foundation of traditional medicine systems worldwide. Contemporary pharmaceutical research continues to recognize the significant contribution of natural products in drug discovery, with approximately 40% of currently marketed drugs having natural origins or being derived from natural product scaffolds [1]. Among the diverse array of medicinal plants, succulent species have attracted particular attention due to their unique adaptations to harsh environmental conditions, which often correlate with the production of specialized secondary metabolites possessing biological activity [2].

Caralluma fimbriata Wall., belonging to the family Apocynaceae (formerly Asclepiadaceae), represents a medicinally significant succulent plant species indigenous to the Indian subcontinent. This xerophytic herb has been extensively utilized in traditional Ayurvedic and folk medicine systems, particularly among tribal communities, for the management of various ailments including diabetes, obesity, cardiovascular disorders, and gastrointestinal conditions [3,4]. The species is characterized by its distinctive fringed corolla lobes, succulent stems, and remarkable ability to survive in arid environments with minimal water availability.

Ethnobotanical investigations have documented the traditional consumption of *C. fimbriata* as both a medicinal agent and famine food, with communities utilizing fresh stems, decoctions, and powdered preparations for appetite suppression, blood glucose regulation, and general health maintenance [5]. Modern pharmacological studies have provided scientific validation for several traditional uses, demonstrating significant anti-obesity, hypoglycemic, cardioprotective, and antioxidant activities in experimental models [6,7].

The therapeutic properties of medicinal plants are primarily attributed to their secondary metabolite content, which includes diverse chemical classes such as alkaloids, flavonoids, phenolic compounds,



saponins, terpenoids, and glycosides [8]. These bioactive constituents often exhibit synergistic interactions, contributing to the multi-target therapeutic effects observed in plant-based medicines. Members of the genus *Caralluma* are particularly noted for their content of pregnane glycosides, steroidal compounds that have been associated with appetite regulation and metabolic modulation [9,10].

Despite the documented ethnomedicinal significance and demonstrated biological activities of *C. fimbriata*, comprehensive analytical characterization of its phytochemical constituents remains incomplete. Previous investigations have provided limited insights into the chemical profile of the species, with most studies focusing on crude extracts rather than detailed compositional analysis. Furthermore, standardized analytical protocols for quality assessment and authentication of *C. fimbriata* preparations are currently lacking, hindering the development of standardized herbal products [11].

High-performance liquid chromatography (HPLC) has emerged as a powerful analytical technique for the separation, identification, and quantification of plant secondary metabolites. The technique offers advantages including high resolution, reproducibility, and the ability to analyze complex mixtures of bioactive compounds [12]. HPLC fingerprinting has become an essential tool for quality control, standardization, and authentication of herbal medicines, providing characteristic chromatographic profiles that can serve as chemical signatures for specific plant species [13].

The present investigation was designed to address the existing knowledge gaps through a comprehensive analytical approach combining qualitative phytochemical screening with HPLC profiling of *C. fimbriata* extracts. The primary objectives include: (1) systematic identification of major secondary metabolite classes present in the plant, (2) comparative evaluation of extraction efficiency using different solvent systems, (3) development of characteristic HPLC fingerprints for quality assessment, and (4) correlation of analytical findings with traditional therapeutic applications.

MATERIALS AND METHODS

2.1 Plant Material Collection and Authentication

Fresh specimens of *Caralluma fimbriata* Wall. were collected during the pre-flowering stage from Shrigonda tehsil, Ahmednagar district, Maharashtra, India (GPS coordinates: 18°73'18.734451" N, 74°79' E) at an altitude of approximately 561 meters above sea level. Collection was performed during

optimal morning hours (08:00-10:00 AM) under clear atmospheric conditions to minimize variability associated with diurnal environmental fluctuations. Multiple mature plants were sampled from the same geographical location to ensure representativeness.



Figure 1: *Caralluma fimbriata* Wall. In natural habitat

Taxonomic authentication was performed by the Botanical Survey of India, Pune, with voucher specimen (Authentication No. JVD182) deposited for permanent reference. The collection site represents a typical semi-arid environment characterized by black cotton soil derived from basaltic formations, with average annual rainfall of 448.6 mm and temperature ranging from 18.5°C to 33°C.

2.2 Sample Preparation and Extraction

Collected plant material was thoroughly cleaned under running tap water followed by distilled water to remove surface contaminants. Cleaned samples were shade-dried at ambient temperature (25-30°C) for 15-20 days in a well-ventilated environment to preserve thermolabile compounds. The dried material was mechanically pulverized and passed through a 40-mesh sieve to achieve uniform particle size distribution. Powdered samples were stored in airtight containers under cool, dry conditions until analysis.

Two extraction protocols were employed to maximize recovery of compounds with varying polarities. Methanolic extraction was performed using 100 g of plant powder with methanol (1:10 w/v) by cold maceration for 72 hours with intermittent agitation. The extract was filtered through Whatman No. 1 filter paper and concentrated under reduced pressure using a rotary evaporator at 40-45°C. For



aqueous extraction, plant powder (100 g) was subjected to hot water extraction (1:10 w/v) at 60-70°C for 3 hours, filtered, and freeze-dried to obtain powdered extract.

2.3 Qualitative Phytochemical Screening

Comprehensive phytochemical screening was conducted following established protocols to detect major classes of secondary metabolites. Stock solutions of both extracts were prepared at 100 mg/mL concentration in appropriate solvents. Alkaloid detection was performed using Dragendorff's, Mayer's, and Wagner's reagents with characteristic precipitate formation indicating positive results. Flavonoids were identified through Shinoda test, alkaline reagent test, and lead acetate test based on color development patterns.

Phenolic compounds and tannins were detected using ferric chloride, lead acetate, and gelatin tests with color changes or precipitation confirming presence. Saponin content was evaluated through foam test involving vigorous shaking with water and observation of persistent froth formation. Terpenoids were identified using Salkowski test with reddish-brown interface coloration indicating positive response. Steroid detection employed Liebermann-Burchard reaction, while glycosides were identified through Keller-Killiani, Legal's, and Borntrager's tests.

2.4 HPLC Instrumental Analysis

High-performance liquid chromatographic analysis was conducted to develop characteristic fingerprint profiles of *C. fimbriata* extracts. The HPLC system was equipped with a reversed-phase C18 analytical column for optimal separation of both polar and moderately polar compounds. Mobile phase composition consisted of acetonitrile (50%) and water containing 0.3% acetic acid (50%) to enhance peak resolution and maintain appropriate pH conditions.

Sample preparation involved dissolving 1 mg/mL of extract in the mobile phase followed by membrane filtration. Injection volume was set to 20 μ L with column temperature maintained at 25°C to ensure reproducible chromatographic conditions. Multi-wavelength detection was employed at 210, 230, 254, and 280 nm to maximize compound detection across different chromophore systems. Flow rate was optimized to provide adequate resolution while maintaining reasonable analysis time.

RESULTS AND DISCUSSION

3.1 Qualitative Phytochemical Analysis

Systematic phytochemical screening revealed the presence of diverse secondary metabolite classes in *C. fimbriata* extracts, with notable differences in extraction efficiency between methanol and aqueous solvents. The comprehensive analysis confirmed the chemical complexity of the species, supporting its traditional therapeutic applications through multiple bioactive constituents.

Phytochemical Analysis Results:

- Alkaloids: Strongly positive in methanolic extract, negative in aqueous extract
- Flavonoids: Positive in methanolic extract, weakly positive in aqueous extract
- Phenols & Tannins: Strongly positive in methanolic extract, positive in aqueous extract
- Saponins: Strongly positive in both extracts
- Terpenoids: Strongly positive in methanolic extract, negative in aqueous extract
- Steroids: Positive in methanolic extract, negative in aqueous extract
- Glycosides: Positive in both extracts
- Carbohydrates: Positive in both extracts

The phytochemical analysis demonstrated significant solvent-dependent variations in metabolite extraction. Methanolic extraction proved superior for recovering lipophilic and moderately polar compounds including alkaloids, terpenoids, and steroids, which were either absent or present in trace amounts in aqueous extracts. This pattern reflects the fundamental principle of solubility, where compounds with similar polarity characteristics are preferentially extracted by corresponding solvents.

The exclusive presence of alkaloids in methanolic extracts is particularly significant, as these nitrogen-containing compounds are often associated with pharmacological activities including appetite suppression and metabolic regulation. The detection of terpenoids and steroids primarily in methanol aligns with the known occurrence of pregnane glycosides in *Caralluma* species, compounds that have been linked to anti-obesity effects through mechanisms involving adipogenesis inhibition and lipid metabolism modulation.



Saponins demonstrated equivalent extraction in both solvents, reflecting their amphiphilic nature with both hydrophilic sugar residues and lipophilic aglycone portions. These compounds contribute to cholesterol-lowering and cardioprotective effects, supporting traditional applications in cardiovascular health. The presence of flavonoids and phenolic compounds in both extracts, with higher concentrations in methanol, indicates the occurrence of both aglycones and glycosylated forms, contributing to the antioxidant and anti-inflammatory properties of the plant.

3.2 HPLC Chromatographic Analysis

High-performance liquid chromatographic analysis of *C. fimbriata* extract revealed a complex chemical profile with multiple well-resolved peaks across the chromatographic run. The optimized analytical conditions using acetonitrile-water (50:50) mobile phase with 0.3% acetic acid provided excellent separation efficiency and peak resolution suitable for fingerprint development.

The chromatographic profile demonstrated distinct retention patterns with major peaks eluting at 5.557, 7.923, 12.047, 15.047, 16.736, 20.802, 21.776, 23.183, 24.731, 33.760, 38.118, and 43.925 minutes. This retention pattern indicates the presence of compounds with varying polarities, from highly polar early-eluting compounds to more lipophilic late-eluting constituents.

HPLC spectra of *Caralluma fimbriata* extract & *Caralluma fimbriata* silver nanoparticles

Mobile Phase-
Acetonitrile HPLC- 50%
Water + 0.3% Acetic acid
Sample – 1mg/ml
Column-C18
Wavelength 210,230,254,280 nm
Injection-20 μ l
Culumn temp-25°C

Caralluma fimbriata Extract

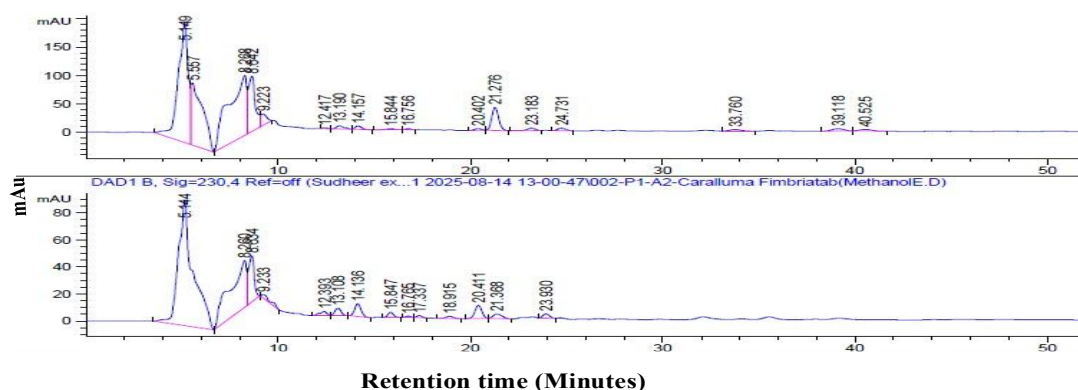


Figure 2: HPLC of *Caralluma fimbriata* Wall. Extract

Multi-wavelength detection at 210, 230, 254, and 280 nm revealed differential UV absorption patterns characteristic of various chromophore systems. Early eluting peaks (5-15 minutes) likely represent highly polar compounds such as organic acids, amino acids, and polar glycosides. Mid-range retention times (15-25 minutes) are consistent with flavonoid glycosides and phenolic acids, while late-eluting peaks (>30 minutes) suggest the presence of less polar compounds including flavonoid aglycones, terpenoids, and steroidal derivatives.

The peak at retention time 5.557 minutes, showing strong absorption at multiple wavelengths, likely corresponds to polar organic acids or amino acid derivatives. Peaks in the 12-16 minute range exhibit UV absorption patterns characteristic of flavonoid compounds, potentially representing quercetin, kaempferol, or their glycosylated derivatives commonly found in medicinal plants.

The significant peaks observed at 23.183 and 24.731 minutes may represent pregnane glycosides or related steroidal compounds, which are characteristic constituents of *Caralluma* species and have been associated with appetite-suppressing and metabolic regulatory activities. The late-eluting peaks



at 38.118 and 43.925 minutes suggest the presence of highly lipophilic compounds, possibly including sterols, triterpenes, or steroidal aglycones.

Comparison with silver nanoparticles synthesized using *C. fimbriata* extract revealed distinct chromatographic differences, with the plant extract showing significantly more complex peak patterns. This complexity underscores the chemical diversity of the natural extract and supports the multi-target therapeutic approach characteristic of traditional herbal medicines.

3.3 Correlation with Therapeutic Applications

The comprehensive analytical profile obtained in this investigation provides substantial scientific support for the traditional therapeutic applications of *C. fimbriata*. The presence of alkaloids, particularly those concentrated in methanolic extracts, correlates well with the plant's traditional use as an appetite suppressant. These compounds likely interact with neurotransmitter systems involved in satiety regulation, including serotonin and dopamine pathways.

The identification of flavonoids, phenolic compounds, and saponins supports the antidiabetic applications of the plant. These compound classes are known to enhance insulin sensitivity, inhibit carbohydrate-digesting enzymes, and protect pancreatic β -cells from oxidative damage. The HPLC peaks corresponding to these compounds provide a chemical basis for the reported hypoglycemic effects observed in experimental studies.

The detection of saponins and phenolic compounds through both phytochemical screening and chromatographic analysis supports the cardioprotective traditional uses. These compounds contribute to lipid profile improvement, endothelial function enhancement, and reduction of cardiovascular risk factors. The multi-compound nature of these effects explains the broad-spectrum cardiovascular benefits associated with traditional *C. fimbriata* preparations.

The strong antioxidant activity traditionally attributed to the plant is well-supported by the presence of multiple antioxidant compound classes including flavonoids, phenolic acids, and tannins. The HPLC peaks in the mid-retention range likely represent these antioxidant constituents, which contribute to cellular protection against oxidative stress and chronic disease prevention.



CONCLUSION

This comprehensive investigation successfully characterized the phytochemical composition and chromatographic profile of *Caralluma fimbriata* Wall., providing valuable scientific insights into the chemical basis of its traditional therapeutic applications. The systematic analysis revealed significant chemical diversity with multiple classes of bioactive secondary metabolites including alkaloids, flavonoids, phenolic compounds, saponins, terpenoids, steroids, and glycosides.

The solvent-dependent extraction patterns demonstrated the importance of appropriate extraction methodology for maximizing recovery of target compounds. Methanolic extraction proved superior for alkaloids, terpenoids, and steroids, while aqueous extraction was effective for saponins and polar glycosides. This information is crucial for optimizing extraction protocols in pharmaceutical and nutraceutical applications.

HPLC analysis established characteristic fingerprint profiles that can serve as quality control markers for authentication and standardization of *C. fimbriata* preparations. The identification of specific retention patterns and UV absorption characteristics provides a foundation for developing analytical standards and ensuring product consistency in commercial formulations.

The strong correlation between analytical findings and traditional therapeutic uses validates the ethnomedicinal knowledge associated with this species. The presence of compounds known to influence appetite regulation, glucose metabolism, cardiovascular function, and oxidative stress provides mechanistic support for the documented biological activities.

Future research directions should focus on isolation and structural characterization of individual bioactive compounds, particularly those corresponding to major HPLC peaks. Quantitative analysis, bioactivity-guided fractionation, and detailed pharmacological evaluation will further enhance understanding of the therapeutic potential of *C. fimbriata*.

The findings of this investigation contribute significantly to the scientific knowledge base supporting the development of evidence-based herbal medicines derived from *C. fimbriata*. The established analytical protocols and chemical profiles will facilitate quality control, standardization, and regulatory compliance for botanical products derived from this medicinally important species.



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NUTRITIONAL ANALYSIS OF SOME WILD EDIBLE PLANT SPECIES FROM THE PART OF THE NORTHERN WESTERN GHATS, MAHARASHTRA

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ABSTRACT

Wild edible plants constitute an irreplaceable nutritional resource for indigenous and rural communities inhabiting ecologically sensitive zones such as the Western Ghats of India. The present investigation undertook a systematic proximate and mineral analysis of five plant taxa — *Amaranthus viridis* L., *Colocasia esculenta* (L.) Schott, *Dioscorea bulbifera* L., *Moringa oleifera* Lam., and *Cassia tora* L. — collected from designated forest localities in the northern Western Ghats, Maharashtra. Proximate parameters, including moisture, crude protein, crude fat, total ash, and nitrogen-free extractives, were quantified following AOAC (2016) protocols, while calcium and iron were determined by atomic absorption spectrophotometry. Considerable interspecific variation was recorded across all parameters. *Moringa oleifera* registered the highest crude protein (18.7 g/100 g dry weight) and mineral concentrations (Ca: 240 mg/100 g; Fe: 8.1 mg/100 g), underscoring its recognized status as a high-value nutritional crop. *Dioscorea bulbifera* exhibited the greatest carbohydrate fraction (24.5 g/100 g), consistent with its role as a calorie-dense subsistence food during seasonal food shortages. *Cassia tora* and *Amaranthus viridis* displayed protein and iron values substantially exceeding many cultivated leafy vegetables reported in the literature. Collectively, the data establish that these taxa are nutritionally competitive with conventional dietary staples and carry therapeutic implications linked to their reported phytochemical profiles. These findings advocate for evidence-based integration of wild plant taxa into national nutrition strategies and support their prioritization in conservation policy frameworks for biodiversity hotspots.

KEYWORDS

Wild edible plants; proximate composition; mineral analysis; Western Ghats; nutritional security; biodiversity hotspot; underutilized crops



INTRODUCTION

Biodiversity-rich ecosystems provide numerous ecological services, among which the provision of diverse, nutrient-dense food for human use stands out as highly tangible but often overlooked. Wild edible plants—non-cultivated vascular species gathered from natural or semi-natural habitats for food—offer critical dietary support to communities with limited access to commercial food supplies (Bharucha and Pretty, 2010). In the Global South, these plants often serve as more than supplements; they supply essential micronutrients, fiber, and calories during post-harvest lean periods or economic hardships (Sunderland, 2011). The Food and Agriculture Organization regularly highlights wild forest foods' role in enhancing household nutrition and resilience, especially for forest-dwelling groups (FAO, 2013).

The Western Ghats, stretching about 1,600 km along India's Deccan Plateau's western edge, rank among the world's eight hottest biodiversity hotspots (Myers et al., 2000). This range, fueled by orographic rainfall, hosts a vegetation mosaic from lowland tropical wet evergreen forests to high-elevation montane grasslands, supporting over 7,400 flowering plant species—including around 2,500 endemics (Mittermeier et al., 2004). Many of these plants hold traditional food value, particularly for long-resident Adivasi (indigenous tribal) communities (Patil and Patil, 2007; Kshirsagar and Singh, 2001).

In the northern Western Ghats' Sahyadri ranges of Maharashtra, semi-deciduous and moist deciduous forests sustain various wild edibles. Kokani, Warli, and Mahadev Koli tribes actively harvest these for food and medicine, using leaves, tubers, fruits, bark, and seeds from multiple families (Chopra et al., 1956; Gaikwad et al., 2014). Yet, quantitative biochemical data on their nutritional profiles remain scarce or confined to qualitative ethnobotanical accounts, hindering inclusion in nutritional databases and policy efforts against food insecurity.

This study examines five commonly harvested wild species from the region. *Amaranthus viridis* L. (Amaranthaceae), a widespread weedy annual, provides steamed greens prized by tribal women for iron benefits postpartum (Grubben and van Sloten, 1981). *Colocasia esculenta* (L.) Schott (Araceae), a semi-cultivated aroid, has leaves cooked with alkali to detoxify calcium oxalate; wild and cultivated forms overlap locally (Matthews, 2004). *Dioscorea bulbifera* L. (Dioscoreaceae), a climbing yam, yields aerial bulbils as famine food, with tubers treated to remove bitter diterpenoids (Wilkin, 1999). *Moringa*



oleifera Lam. (Moringaceae), a rapid-growing tree, supplies leaves, pods, and seeds across tropical Asia and Africa; its leaves rank among the planet's most nutrient-packed foods (Fahey, 2005). *Cassia tora* L. (Fabaceae), or chakramarda, offers tender leaves as vegetables and roasted seeds as coffee alternatives, noted for anthraquinones and flavonoids (Neamsuvan et al., 2015).

Although these species' nutritional importance is recognized, peer-reviewed data from northern Western Ghats specimens are limited. Indian wild edible databases lack completeness and site-specificity, often pooling data from distant areas affected by agroclimate, phenology, or genetics (Longvah et al., 2017). Prior studies also covered few parameters, limiting comparisons to dietary standards. This research fills these gaps via standardized multi-parameter analysis of field-collected samples, producing location-specific, consistent data to guide diets and conservation.

Specific objectives include: (i) assessing proximate composition (moisture, crude protein, ether extract, total ash, carbohydrates) for the five taxa from northern Western Ghats; (ii) measuring calcium and iron via atomic absorption spectrophotometry; (iii) comparing results to cultivated vegetable data and dietary reference intakes; and (iv) assessing their role in nutritional security and integration into formal food systems.

MATERIALS AND METHODS

2.1 Study Area and Ecological Context

The field investigation was carried out across designated collection localities within the northern Western Ghats of Maharashtra, India, spanning approximately 19°N to 21°N latitude and 73°E to 74°E longitude. The terrain is defined by lateritic plateaus (maals), river gorge forests, and mixed deciduous hill slopes, with mean annual precipitation ranging from 1,000 mm in the rain-shadow leeward areas to over 3,000 mm on the windward escarpments (Myers et al., 2000). The region experiences a pronounced tropical monsoon regime with a distinct dry season (November to May) and a wet season (June to October), during which the majority of wild leafy plants reach peak vegetative growth. Mean annual temperature ranges from 22°C to 30°C at lower elevations, with montane localities experiencing cooler mean temperatures of 15°C to 22°C. The vegetation is classified as Southern Tropical Moist Deciduous Forest and Northern Tropical Semi-evergreen Forest according to Champion and Seth (1968), with anthropogenic grasslands and agricultural margins contributing additional microhabitats for weedy edible species such as *Amaranthus viridis* and *Cassia tora*.



2.2 Plant Collection and Taxonomic Authentication

Collection of plant material was undertaken during the peak vegetative season (June to September) over two consecutive years to account for inter-annual variation in plant chemistry and to ensure adequate biomass for replicated analyses. Sampling transects were established in consultation with local tribal informants who possessed demonstrable knowledge of the species in question, ensuring that only parts customarily consumed were collected. For leafy species (*Amaranthus viridis*, *Colocasia esculenta*, *Moringa oleifera*, and *Cassia tora*), fully expanded, healthy, unblemished leaves from the upper one-third of the canopy or plant were selected to minimize variation attributable to leaf age and shading status. For *Dioscorea bulbifera*, mature aerial bulbils were harvested after the aerial bulbils had attained full size but before senescence of the vine, as this stage corresponds to maximum starch accumulation and traditional harvest practice.

A minimum of three geographically separated populations of each species were sampled to reduce the influence of population-level chemical variation on mean nutritional estimates. Collected material from each population was pooled prior to laboratory processing to obtain a representative composite sample. Taxonomic identity of each species was confirmed using the regional floristic treatments of Jain and Rao (1977), Cooke (1903), and, where necessary, the Flora of British India (Hooker, 1876). Herbarium voucher specimens were prepared, labelled with full collection data, and deposited in the institutional herbarium for future reference. The correct nomenclature and authority citations follow the International Plant Names Index (IPNI, 2023).

2.3 Sample Preparation

Freshly collected plant material was transferred to the laboratory within six hours of harvest under ambient temperature to minimize enzymatic degradation. Each sample was subjected to three washes: an initial rinse in running tap water to remove soil, particulate matter, and surface microbiota; a second wash in a 0.1% potassium permanganate solution for two minutes as a surface disinfectant; and a final rinse in double-distilled water. Washed material was blotted dry with sterile absorbent paper and arranged in single layers on clean nylon trays for shade drying in a well-ventilated room maintained at 25–30°C. Shade drying rather than oven drying was chosen for the drying stage because it is more representative of traditional preparation practices in the study communities, and because laboratory



studies have demonstrated that oven drying at elevated temperatures can cause appreciable losses of heat-labile vitamins and certain mineral complexes (Dewanto et al., 2002).

Drying was continued for 10–14 days, with samples weighed at 48-hour intervals until three consecutive weighing intervals showed less than 0.5% change in mass, at which point the samples were considered to have reached air-dry equilibrium. The dried material was transferred to a Wiley mill and ground to pass through a 60-mesh (250 μm) stainless steel sieve, yielding a homogeneous, free-flowing powder. Powdered samples were divided into replicate portions, each sealed in airtight amber glass vials, and stored at room temperature in a desiccator charged with silica gel until analysis. All analyses were initiated within four weeks of sample preparation to minimize oxidative degradation of lipid and phenolic fractions (Sadasivam and Manickam, 2008).

2.4 Proximate Analysis

Proximate composition was determined following the standardized protocols of the Association of Official Analytical Chemists (AOAC, 2016), which represent the internationally recognized reference methods for plant food analysis. Moisture content was determined gravimetrically by drying approximately 2 g of fresh plant tissue in a forced-air oven at 105°C to constant weight, with the moisture percentage calculated as the loss in mass divided by the initial fresh mass, expressed as a percentage (AOAC method 934.01). Crude protein was estimated by the macro-Kjeldahl procedure (AOAC method 984.13), in which total nitrogen is liberated by acid digestion in concentrated sulphuric acid with a copper sulphate and potassium sulphate catalyst, converted to ammonia by alkaline distillation, and titrated against standardized boric acid. Total protein content was calculated by applying a nitrogen-to-protein conversion factor of 6.25, consistent with AOAC guidelines for mixed plant tissues.

Crude fat was determined by continuous extraction in a Soxhlet apparatus using petroleum ether (boiling point range 40–60°C) as the extracting solvent for six hours, after which the solvent was evaporated and the residual fat fraction weighed gravimetrically (AOAC method 920.39). Total ash content was determined by complete incineration of 1 g of dried powdered sample in a pre-tared porcelain crucible in a muffle furnace at 550°C for six hours, with cooling in a desiccator before weighing (AOAC method 942.05). Carbohydrates were calculated by difference, subtracting the sum of moisture, crude protein, crude fat, and ash percentages from 100, thereby representing nitrogen-free



extractives including available starch, non-starch polysaccharides, and soluble sugars. All proximate analyses were conducted in triplicate for each species, and results are expressed as mean \pm standard deviation on a dry weight basis.

2.5 Mineral Analysis

Calcium and iron concentrations were determined by flame atomic absorption spectrophotometry (AAS) following wet acid digestion of the powdered samples. Approximately 0.5 g of each sample was transferred to a digestion vessel and treated with 5 mL of concentrated nitric acid (65% HNO₃, analytical grade) and 1 mL of 70% perchloric acid (HClO₄). The mixture was heated gradually on a sand bath, commencing at 80°C and increasing stepwise to 200°C, until a clear, colourless digest was obtained. Digests were cooled, filtered through Whatman No. 42 filter paper, and diluted to 25 mL with 1% HNO₃ in volumetric flasks. Calcium and iron concentrations in the digestates were measured on a PerkinElmer A Analyst 700 atomic absorption spectrometer using hollow-cathode lamps at characteristic wavelengths of 422.7 nm for calcium and 248.3 nm for iron, with appropriate matrix-matched calibration standards prepared from certified stock solutions (Merck CertiPUR). Quality control was maintained through simultaneous analysis of a certified reference material (NIST SRM 1570a Trace Elements in Spinach Leaves) at the beginning and end of each analytical run, with recoveries consistently within 95–102% of certified values (PerkinElmer, 2000). All mineral analyses were performed in triplicate.

2.6 Statistical Analysis

All analytical data are expressed as mean \pm standard deviation of triplicate determinations. One-way analysis of variance (ANOVA) was applied to test for significant differences in each nutritional parameter among the five species, using IBM SPSS Statistics version 26.0. Where ANOVA indicated a statistically significant overall effect ($p < 0.05$), post-hoc pairwise comparisons were performed using Tukey's Honestly Significant Difference (HSD) test with a familywise error rate of $\alpha = 0.05$. Pearson correlation coefficients were computed between selected pairs of nutritional variables to assess nutritional interrelationships across species.

RESULTS AND DISCUSSION

3.1 Proximate Composition

The proximate nutritional profiles of the five wild edible taxa are presented in Table 1. Statistically significant interspecific differences were recorded for all parameters (one-way ANOVA, $p < 0.01$), confirming that the nutritional profiles of the studied taxa are distinctly differentiated rather than homogeneous.

Moisture content ranged from 64.2% in *Moringa oleifera* to 72.0% in *Colocasia esculenta*. High moisture content in *C. esculenta* ($72.0 \pm 1.1\%$) is consistent with the succulent mesophytic character of its leaf lamina and reflects the high water-holding capacity of its mucilaginous parenchyma cells. The comparatively lower moisture values in *D. bulbifera* ($65.3 \pm 0.9\%$) and *M. oleifera* ($64.2 \pm 1.0\%$) are associated with a higher concentration of dry matter per fresh weight unit, which has direct implications for nutrient density calculations on a fresh-weight basis.

Crude protein content showed the widest absolute variation among all measured parameters, spanning from 6.9 g/100 g (dry weight) in *Dioscorea bulbifera* to 18.7 g/100 g in *Moringa oleifera*. The high protein content of *M. oleifera* leaves, confirmed in the present investigation, is well established in the literature and is attributable to the presence of substantial concentrations of essential amino acids, including leucine, lysine, and methionine, alongside the more abundant non-essential amino acids (Fahey, 2005; Gopalakrishnan et al., 2016). *Cassia tora* (14.1 ± 0.6 g/100 g) and *Amaranthus viridis* (13.2 ± 0.5 g/100 g) registered protein values that surpass commonly consumed cultivated leafy vegetables such as spinach (*Spinacia oleracea*, ca. 9.2 g/100 g DW) and fenugreek (*Trigonella foenum-graecum*, ca. 11.3 g/100 g DW) as reported by Longvah et al. (2017). *Colocasia esculenta* leaves yielded 10.5 ± 0.4 g/100 g protein, and *D. bulbifera* the lowest protein fraction among the five taxa, reflecting the predominantly starchy character of the bulbil storage tissue.

Crude fat content was relatively low across all species, ranging from 0.9 ± 0.1 g/100 g in *D. bulbifera* to 3.5 ± 0.3 g/100 g in *M. oleifera*. These modest lipid values are nutritionally favourable from the perspective of calorie density for consumers managing cardiovascular risk, and the fat fractions of leafy species in this range typically contain appreciable proportions of α -linolenic acid (omega-3 fatty acid), consistent with observations reported for *M. oleifera* and *A. viridis* by Bhatt et al. (2020). Total ash content, reflecting the inorganic mineral residue of the dry tissue, ranged from 2.0 ± 0.2 g/100 g in *C.*

esculenta to 3.4 ± 0.2 g/100 g in *M. oleifera*, a ranking that broadly parallels the iron and calcium values quantified by AAS (Table 2).

The carbohydrate fraction, computed by difference and therefore representing the aggregate of all non-fat, non-protein, non-ash organic carbon compounds, was highest in *D. bulbifera* (24.5 ± 1.2 g/100 g), substantially exceeding the values for the leafy species, which ranged from 10.2 g/100 g (*M. oleifera*) to 13.7 g/100 g (*C. esculenta*). The elevated carbohydrate content of *D. bulbifera* is consistent with its botanical role as a storage organ in which photosynthetically fixed carbon is accumulated as starch, and explains the plant's traditional utilization as a calorically dense food during periods of primary crop failure (Wilkin, 1999).

Table 1. Proximate composition of five wild edible plant species from the northern Western Ghats (mean \pm SD, dry weight basis, n = 3).

Species	Moisture (%)	Crude Protein (%)	Crude Fat (%)	Carbohydrates (%)	Ash (%)
<i>Amaranthus viridis</i>	68.5 ± 0.8	13.2 ± 0.5	2.3 ± 0.2	12.8 ± 0.6	3.2 ± 0.1
<i>Colocasia esculenta</i>	72.0 ± 1.1	10.5 ± 0.4	1.8 ± 0.1	13.7 ± 0.9	2.0 ± 0.2
<i>Dioscorea bulbifera</i>	65.3 ± 0.9	6.9 ± 0.3	0.9 ± 0.1	24.5 ± 1.2	2.4 ± 0.2
<i>Moringa oleifera</i>	64.2 ± 1.0	18.7 ± 0.7	3.5 ± 0.3	10.2 ± 0.5	3.4 ± 0.2
<i>Cassia tora</i>	69.1 ± 0.7	14.1 ± 0.6	2.0 ± 0.2	11.9 ± 0.7	2.9 ± 0.1

3.2 Calcium and Iron Content

The concentrations of calcium and iron in the five taxa are summarized in Table 2. *Moringa oleifera* consistently recorded the highest values for both minerals (Ca: 240 ± 5.1 mg/100 g DW; Fe: 8.1 ± 0.4 mg/100 g DW), establishing it as the mineral-richest taxon in the study. *Cassia tora* ranked second for iron content (6.5 ± 0.3 mg/100 g DW) and third for calcium (200 ± 3.5 mg/100 g DW), while *Amaranthus viridis* yielded calcium and iron values of 210 ± 4.2 and 5.8 ± 0.3 mg/100 g DW respectively. *Colocasia esculenta* presented moderate mineral values (Ca: 180 ± 3.8 mg/100 g DW; Fe: 4.2 ± 0.2 mg/100 g DW), and *Dioscorea bulbifera* recorded the lowest concentrations in both categories (Ca: 95 ± 2.1 mg/100 g DW; Fe: 2.9 ± 0.2 mg/100 g DW), consistent with the mineral-poor character typical of starchy underground storage organs in comparison with photosynthetically active leaf tissue.

A strong positive correlation was observed between calcium and iron concentrations across the five species (Pearson $r = 0.96$, $p < 0.01$), suggesting that species with high calcium accumulation capacity also tend to accumulate iron efficiently, possibly reflecting shared uptake mechanisms or common soil conditions at the collection sites. The iron values recorded for *M. oleifera* (8.1 mg/100 g) and *Cassia tora* (6.5 mg/100 g) are noteworthy in the context of the recommended daily intake for iron, which is set at 17–21 mg/day for women of reproductive age in India according to the Indian Council of Medical Research (ICMR, 2020), given that a 100-gram serving of these species could contribute approximately 31–48% of this requirement.

Table 2. Calcium and iron content of five wild edible plant species from the northern Western Ghats (mean \pm SD, mg/100 g dry weight, $n = 3$).

Species	Calcium (mg/100 g DW)	Iron (mg/100 g DW)
<i>Amaranthus viridis</i>	210 ± 4.2	5.8 ± 0.3
<i>Colocasia esculenta</i>	180 ± 3.8	4.2 ± 0.2

Species	Calcium (mg/100 g DW)	Iron (mg/100 g DW)
<i>Dioscorea bulbifera</i>	95 ± 2.1	2.9 ± 0.2
<i>Moringa oleifera</i>	240 ± 5.1	8.1 ± 0.4
<i>Cassia tora</i>	200 ± 3.5	6.5 ± 0.3

3.3 Discussion

The data presented here contribute empirical nutritional evidence for five wild taxa of ethnobotanical significance in the northern Western Ghats, a region whose traditional food systems have rarely been subjected to standardized biochemical analysis. The overarching finding — that all five species display nutritional profiles that are at minimum comparable to, and in several parameters superior to, commonly cultivated vegetables — carries implications for food policy, conservation management, and the documentation of indigenous dietary knowledge.

The protein content of *Moringa oleifera* (18.7 g/100 g DW) recorded in the present study falls within the range of 17–27 g/100 g DW compiled by Fahey (2005) from globally sourced *M. oleifera* leaf samples, confirming that specimens from the northern Western Ghats are nutritionally representative of the species and not outliers. The slight variation from the uppermost reported values may reflect differences in leaf developmental stage, soil nitrogen availability, or water stress at the time of collection, all of which modulate leaf nitrogen concentrations in *M. oleifera* (Bhatt et al., 2020). The combination of high protein and high mineral content makes *M. oleifera* a candidate for incorporation into therapeutic food formulations targeting protein-energy malnutrition and iron-deficiency anaemia, conditions whose prevalence remains elevated in tribal districts of Maharashtra (NFHS-5, 2021).

Amaranthus viridis and *Cassia tora* emerged as the second and third most protein-rich taxa in the study, with values that are consistent with data reported by Grubben and van Sloten (1981) and Neamsuvan et al. (2015) respectively. The protein quality of *A. viridis* is additionally supported by evidence in the literature that the genus *Amaranthus* contains well-balanced essential amino acid profiles, with lysine content that is notably higher than in cereal grains, making it a nutritionally synergistic complement to



cereal-dominated diets (Bressani, 1994). In rural and tribal communities of the northern Western Ghats, where maize and sorghum constitute the dietary base and protein-energy malnutrition is documented (NFHS-5, 2021), regular consumption of *A. viridis* leaves could plausibly contribute to improved protein quality of the diet without requiring changes in staple food preference.

The iron values recorded for *M. oleifera* (8.1 mg/100 g DW), *Cassia tora* (6.5 mg/100 g DW), and *A. viridis* (5.8 mg/100 g DW) are considerably higher than the 2.7 mg/100 g DW for spinach or 1.2 mg/100 g DW for cabbage as listed in the Indian Food Composition Tables (Longvah et al., 2017). However, it must be noted that the bioavailability of non-haem iron from plant sources is substantially influenced by the concurrent intake of enhancers (ascorbic acid, organic acids) and inhibitors (phytate, oxalic acid, polyphenols) present in the food matrix (Hallberg and Hulthen, 2000). *Moringa oleifera* leaves, which contain documented ascorbic acid concentrations of 220 mg/100 g fresh weight (Fahey, 2005), may partially offset phytate-mediated inhibition of iron absorption, though in-vitro digestion studies and human bioavailability trials would be required to quantify this interaction definitively.

Colocasia esculenta leaves exhibited moderate protein (10.5 g/100 g DW) and minerals (Ca: 180 mg; Fe: 4.2 mg/100 g DW), consistent with published data for taro leaves from Asian germplasm (Matthews, 2004). The high moisture content of *C. esculenta* (72.0%) reduces its apparent fresh-weight nutritional density relative to drier leafy species, a consideration relevant to dietary intake estimates based on fresh-weight consumption data. Importantly, *C. esculenta* leaves contain calcium oxalate rap hides and prisms that must be inactivated by prolonged boiling with alkaline agents before the leaves are safe for consumption; this traditional processing step presumably also leaches some water-soluble nutrients, a loss that is not captured by the present analysis of dried powders and which warrants attention in future studies employing simulated cooking methods.

Dioscorea bulbifera occupied a nutritionally distinct position among the five taxa, with the highest carbohydrate content (24.5 g/100 g DW) but the lowest protein and mineral concentrations. This profile accurately reflects the storage function of the aerial bulbil, which is primarily a starch repository rather than a metabolically active tissue. The role of *D. bulbifera* as a famine food and calorie supplement during the monsoon season — when cultivated crops are not yet mature — is therefore anchored in nutritional reality: the bulbil provides energy in a form that is culturally acceptable, freely available, and requiring minimal agricultural inputs. Nevertheless, the low iron content (2.9 mg/100 g DW) of this



species means that communities relying heavily upon it during lean periods would benefit from concurrent consumption of iron-rich complementary foods such as *M. oleifera* or *Cassia tora* to prevent nutritional anaemia.

From the perspective of functional food chemistry, all five taxa investigated here have been associated with bioactive phytochemical constituents that complement their nutritive value. Mishra et al. (2020) documented that wild leafy plants from the Western Ghats region contain phenolic acids, flavonoids, and tannins at concentrations correlated with significant antioxidant capacity in DPPH and ABTS free-radical scavenging assays. *Cassia tora* is of particular pharmacological interest because its anthraquinone derivatives — emodin, chrysophanol, and physcion — exhibit hepatoprotective, antifungal, and laxative activity, and its seeds are a commercial source of cassia gum, a galactomannan-based food additive approved by the European Food Safety Authority (Neamsuvan et al., 2015). The phytochemical and nutraceutical attributes of these species therefore add value beyond their basic nutritional contributions, supporting their promotion in integrative nutrition programmes that recognize food's preventive health dimensions.

The broader context in which these findings must be interpreted includes the accelerating erosion of traditional food knowledge in the northern Western Ghats. Gaikwad et al. (2014) documented a 40% reduction in the frequency of wild plant consumption among households in Western Maharashtra over a 20-year period, driven by market food accessibility, urbanization, and social stigma around "forest foods." Scientific validation of the nutritional quality of these species, as provided by the present investigation, can serve as a counternarrative to the perception that wild foods are nutritionally inferior, potentially stimulating conservation-oriented consumption and supporting the inclusion of these species in Integrated Child Development Scheme (ICDS) supplementary feeding programmes where local procurement is feasible.

Certain limitations of the present study merit acknowledgement. First, the proximate and mineral analyses provide quantitative data on nutrient content but do not address bioavailability, which depends on anti-nutritional factor concentrations, processing methods, and gut-level interactions that were outside the scope of this investigation. Second, lipid quality — including the fatty acid composition and ratio of omega-3 to omega-6 fatty acids — was not determined, and for species such as *M. oleifera*, where lipid quality is of nutritional significance, fatty acid profiling would add substantial



interpretive value. Third, the calculated carbohydrate fraction by difference includes both available starch and dietary fibre, and their separate quantification by enzymatic methods (AOAC method 991.43 for total dietary fibre) would improve the nutritional characterization, particularly for *D. bulbifera*, whose resistant starch content may contribute to its prebiotic properties. These gaps represent logical directions for future research building on the baseline data reported here.

CONCLUSION

This study provides quantitative nutritional evidence establishing that five wild edible taxa collected from the northern Western Ghats — *Amaranthus viridis*, *Colocasia esculenta*, *Dioscorea bulbifera*, *Moringa oleifera*, and *Cassia tora* — are nutritionally competitive with, and in several respects superior to, widely consumed cultivated vegetables. *Moringa oleifera* stands out as the most nutritionally complete species among those examined, combining the highest protein (18.7 g/100 g DW), the most elevated calcium (240 mg/100 g DW), and the greatest iron concentration (8.1 mg/100 g DW) of any species in the study set. *Cassia tora* and *Amaranthus viridis* contribute significant protein and iron values that make them particularly relevant to addressing iron-deficiency anaemia in communities where they occur. The carbohydrate-rich profile of *Dioscorea bulbifera* validates its ethnobotanical role as an energy-dense famine food, though its low mineral content argues for dietary complementation with iron- and calcium-rich species when consumption is intensive.

The findings collectively demonstrate that wild edible plants of the northern Western Ghats represent an underutilized nutritional resource whose potential contribution to household dietary quality has been largely invisible in formal nutrition policy. This invisibility arises partly from the absence of geographically specific, methodologically rigorous analytical data — a gap that the present investigation partially addresses. Future research should extend the taxonomic coverage to additional wild edible species in the region, incorporate bioavailability assessments through in-vitro digestion models, and quantify anti-nutritional factors and total dietary fibre to generate a comprehensive nutritional risk-benefit profile for each species. Parallel ethnobotanical documentation of consumption frequency, preparation methods, and cultural transmission of knowledge regarding these plants would enable the construction of realistic dietary intake estimates and facilitate evidence-based integration of wild plant taxa into supplementary nutrition programmes and biodiversity conservation agendas.



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UNCOVERING THE PHARMACOLOGICAL POTENTIAL OF GINGER: A REVIEW ON ITS ANTI-INFLAMMATORY AND ANTI-OXIDANT PROPERTIES

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ABSTRACT

For thousands of years, people have utilized ginger (*Zingiber officinale*) rhizomes as a medicinal herb. Ginger's chemical constituents are anticipated to provide health advantages, particularly as anti-inflammatory and antioxidant substances that may function as immunomodulators. Numerous pertinent scientific studies that supported ginger's immunomodulatory potential due to its anti-inflammatory and an antioxidant property served as the foundation for the literature study on the plant's function in immune system regulation. Prior to delving into the intricacies of the herbal plants, the biology of inflammation and oxidative stress was discussed.

KEYWORDS

Anti- Inflammatory, Antioxidant Properties

INTRODUCTION

The Zingiberaceae family includes ginger (*Zingiber officinale* Rosc.). Since it originated in South-East Asia, it has long been used as a condiment and spice in many nations.^[1] Ginger (*Zingiber officinale* Roscoe), which is grown extensively in the southeast and adjacent nations of Asia, is generated and collected as an uneven, bumpy rhizome. There is no concrete information about the ginger plant's origin because it has been grown here for so long.^[2] Ginger's biological action comes from its volatile and non-volatile chemical composition. Sesquiterpenes and monoterpenoids are volatile components of ginger that are essential oils with distinct fragrances. However, ginger's potent, fiery flavor comes from non-volatile components like gingerol, shogaol, zingerone, and paradol. Gingerol, the main component of raw ginger, is later converted into shogaol, zingerone, and paradol in ginger-based goods.^[3] While scientific evidence supports ginger's anti-inflammatory and antioxidant properties, its putative



neuroprotective benefit is a more specialized and understudied bioactivity.^[4] In addition to infectious agents like bacteria, viruses, and parasites, physical and chemical factors like heat, acid, cigarette smoke, and foreign objects can cause inflammatory disorders including gastritis, esophagitis, and hepatitis, which are risk factors for human cancer.^[5] Ginger ingestion may help reduce naturally occurring quadriceps muscle soreness prior to moderate-intensity cycling exercise, although clinical results are mixed. For example, Black et al. (2008)^[6] conducted a double-blind, placebo-controlled study and found that a 2 g dose of ginger did not significantly reduce muscle soreness or improve performance during or after cycling exercise. Nevertheless, ginger contains bioactive compounds such as gingerols and shogaols that have demonstrated anti-inflammatory properties in preclinical studies.^[7] These compounds may decrease the expression of pro-inflammatory cytokines like TNF- α and IL-1 β . However, as noted by Mashhadi et al. (2013)^[8] while laboratory and animal studies are promising, further research is required to confirm the anti-inflammatory effects of ginger in human populations. Ginger's anti-inflammatory properties, such as its ability to lower oxidative stress, block pro-inflammatory cytokines, and alter inflammatory pathways, have been shown in studies. These insights have enabled mainstream medicine to embrace ginger as a natural remedy for inflammatory conditions. This comprehensive investigation examines the phytochemical features of ginger, emphasizing the active compounds and antioxidants that contribute to its anti-inflammatory qualities.^[9] Antioxidant-derived immunomodulators promote general health by regulating the immunological response and oxidant-antioxidant balance. Antioxidants work both directly and indirectly by eliminating reactive oxygen-nitrogen species and improving the body's antioxidant equilibrium.^[10]

Ginger's pharmacological properties (*Zingiber officinale* Rosc.)

The anti-inflammatory properties of ginger

Ginger has long been used as an anti-inflammatory, and many of its ingredients have been shown to have anti-inflammatory properties.^[11] Ginger has been shown to block the vanilloid nociceptor, interfere with the inflammatory cascade, and decrease prostaglandin biosynthesis.^[12,13] Ginger lowers prostaglandin synthesis by blocking cyclooxygenase-1 and cyclooxygenase-2, which has been shown to have pharmacological similarities to non-steroidal anti-inflammatory medications (NSAIDs). But what distinguishes ginger from NSAIDs is its ability to inhibit 5-lipoxygenase, which in turn suppresses



the formation of leukotrienes.^[12]The dual inhibitors of 5-lipoxygenase and cyclooxygenase, which may have a superior therapeutic profile and fewer side effects than NSAIDs, were discovered prior to this.^[13]A ginger extract (EV.EXT.77) from *Zingiber officinale* (and *Alpina galanga*) inhibits the activation of multiple genes implicated in the inflammatory response, including those encoding cytokines, chemokines, and the inducible enzyme cyclooxygenase-2. This finding offered the first proof that ginger alters the molecular pathways that cause chronic inflammation.^[14] The opportunity to standardize and improve ginger products in terms of their effects on particular biomas is presented by the identification of the molecular targets of various ginger components. Ginger has about 40 distinct antioxidant chemicals that can be utilized to treat a range of inflammatory diseases.^[15]Therefore, ginger's shogaols, gingerols, and diarylheptanoids may help lessen some inflammatory symptoms. Certain disorders, such as obesity, which is characterized by elevated levels of pro-inflammatory markers, can be treated with ginger. The paraoxonase-1 mechanism, which stops lipidic substances from accumulating in vessel walls, makes this particularly true.^[12]TNF- α levels decreased at the end of the ginger treatment period, according to certain studies, indicating that ginger may be utilized as an adjuvant anti-inflammatory treatment for specific conditions.^[15] Furthermore, the synthesis of inflammatory mediators such as prostaglandin E2, NO, inflammatory cytokines (TNF- α), interleukin-1 β (IL-1 β), and pro-inflammatory transcription factors (NF- κ B) is inhibited by ginger compounds including 6-gingerol and 6-shogaol.^[12] They also inhibit COX-1 and COX-2. Because 6-shogaol inhibits the release of arachidonic acid and decreases the creation of nitric oxide (NO), it has been observed by numerous authors to have a stronger capacity to reduce inflammation.^[16,17]Therefore, ginger's shogaols, gingerols, and diarylheptanoids may help lessen some inflammatory symptoms. Certain disorders, such as obesity, which is characterized by elevated levels of pro-inflammatory markers, can be treated with ginger.^[18]Specifically through the paraoxonase-1 mechanism, which stops lipidic compounds from building up in vessel wall.^[12] Some studies have shown that TNF- α levels decreased following the ginger treatment period^[19], which implies that ginger may be helpful as an adjuvant anti-inflammatory treatment for some conditions. Additionally, by inhibiting the production of inflammatory mediators such as prostaglandin E2, NO, inflammatory cytokines (TNF- α), interleukin-1 β (IL-1 β), and pro-inflammatory transcription factor (NF- κ B), ginger chemicals like 6-gingerol and 6-shogaol diminish inflammation. Furthermore, they suppress COX-1 and COX-2.^[20] Several writers claim that 6-shogaol suppresses arachidonic acid release and lowers nitric oxide (NO) generation more than 6-gingerol.^[21,22]



Ginger's Impact on Inflammatory Conditions

Accordingly, several studies have shown that ginger's bioactive ingredients can successfully lessen the symptoms of chronic inflammatory illnesses.^[23]

Rheumatoid Arthritis

Rheumatoid arthritis (RA), a chronic autoimmune illness, is characterized by joint discomfort in the hands, feet, wrists, shoulders, elbows, hips, and knees. It is distinguished by close connection between innate and adaptive immune system mediators and cell.^[24] Although the exact cause of RA is still unknown, environmental, genetic, and epigenetic variables all play a role. Inflammation of the synovial membrane causes pain, stiffness, and swelling, especially in the morning or after prolonged rest. In addition to the joints and surrounding tissues (muscles and tendons), chronic inflammation can damage other organs such as the kidney, heart, or lung, which can lead to decreased mobility and joint function.^[25] Moreover, high and ongoing inflammation can cause fever, fatigue, asthenia, weight loss, and appetite loss.^[26] Chronic inflammation is clearly caused by oxidative stress and a compromised immune system, even if the pathophysiological processes of RA are not fully understood. ^[27,28] The actual treatments for RA include immunomodulation or immunosuppression and anti-inflammatory medications, although they do not cure the condition. Given that RA is influenced by environmental factors, including nutrition, it seems logical to think that certain foods or minerals with anti-inflammatory and antioxidant properties may be beneficial in this condition.^[29] Ginger's anti-inflammatory and antioxidant properties make it a fantastic choice in this respect. Ginger has been used as an anti-inflammatory in medicine since ancient times. This is now known to be the result of ginger's bioactive chemicals' capacity to inhibit the COX-2 and LOX pathways.^[30] In vitro and in vivo studies have demonstrated the antiarthritic effects of ginger. ^[31] 6-shogaol is one of ginger's most prevalent bioactive substances. In vitro and in vivo, 6-shogaol has shown anti-inflammatory, antioxidant, neuroprotective, and cancer-preventive qualities.^[32] 6-shogaol successfully reduced the development of arthritis symptoms in vivo^[33,34,35] leukocyte infiltration into the tissue, or paw edema.^[36] In an animal model of arthritis, Bashir et al. confirmed that zingerone can reduce oxidative stress and inflammation. ^[37] According to a recent study, 8-shoagol is an effective chemical against synovitis, dramatically reducing inflammation and migration mediated by TNF- α , IL-1 β , and IL-17 in both a RA patient and a 3D synovial culture system. Furthermore, they showed that 8-shogaol therapy restored



joint pathologies in the adjuvant-induced rat model of arthritic arthritis, reduced inflammatory biomarkers in the joints, and improved walking performance by decreasing paw thickness. In 2022, **Marhuenda et al.**^[38] According to a recent study by **Aryeian et al.**, giving 63 RA patients 1.5 g of ginger daily dramatically reduced their levels of hs-CRP and IL-1B.^[39] Furthermore, there was a notable reduction in TNF α in the ginger group.

Inflammatory Bowel Disease

A wide range of chronic inflammatory digestive illnesses with an uncertain etiology are collectively referred to as "inflammatory bowel disease" (IBD). Crohn's disease and ulcerative colitis are examples of these processes. Crohn's disease can develop anywhere in the gastrointestinal tract, from the mouth to the anus, but it usually affects the ascending colon and distal ileum. Although it can affect the entire colon, ulcerative colitis primarily affects the rectum and distal colon. Inflammation is an unequal and uneven process. Ulcerative colitis, as opposed to Crohn's disease, starts in the rectum and progresses to ulcerative proctitis.^[40] The three most common clinical manifestations of ulcerative colitis are diarrhea, bloody mucoid stools, and abdominal pain. In terms of the disease's pathophysiology, it is known that in addition to hereditary variables, there are additional triggering factors, also referred to as environmental precipitants and disease cofactors. In this sense, in genetically predisposed individuals with impaired immune system control, a pathogen infection coupled with a dysfunctional intestinal barrier would be a precipitating factor, resulting in a persistent inflammatory response. Inflammation may arise from the immunological response of the gastrointestinal tract when the equilibrium between commensal bacteria and the immune system is upset. This alteration is more likely to occur in those who are genetically inclined. The gut microbiota plays an important role in the management of IBD.^[41] Concerning the previously reported dysbiosis in patients with ulcerative colitis and Crohn's disease in comparison to controls, Guo et al.^[42] illustrated how ginger can improve the gut microbiota's functioning and restore its diversity. Patients with Crohn's disease and ulcerative colitis are more likely to have firmicutes.^[43] Gut homeostasis depends on toll-like receptors (TLRs), which serve as mediators between the immune system and the gut microbiota. Pathogen-associated molecular patterns (PAMPs), which regulate dendritic cell maturation, adaptive immunity, and innate immunity, are recognized and activated by TLRs. TLR expression increases when these rules are altered, increasing the likelihood of inflammatory cytokines and inflammatory bowel disorders.^[44] TLR4 signaling is linked



to inflammatory bowel disease and the efficacy of pharmaceutical treatment.^[45] Bioactive substances found in a variety of foods can help prevent and treat inflammatory bowel illnesses. Among these substances is glycomacropeptide (GMP), a peptide produced from milk K-casein that has immunomodulatory, antibacterial, and prebiotic qualities. Curcumin is a yellow pigment found in turmeric (*Curcuma longa*), an Indian spice with health benefits. Curcumin improves the altered intestinal barrier function caused by inflammation by lowering the expression of myosin light chain kinase (MLCK). Furthermore, it lessens the quantity of TNF- α , IL-4, IL-6, and IL-13 that MCs generate in response to allergens.^[46] New, efficient medicines and adjuvants are required for IBD because traditional treatment might have negative side effects (including nausea, pancreatitis, and allergic responses) and is usually ineffective in some individuals.^[47] Ginger has long been used to treat infections, diarrhea, and vomiting due to its anti-inflammatory, anti-tumor, anti-ulcer, and antioxidant qualities.^[48] Ginger lowers inflammation in IBD by inhibiting the signal transducer of activators of transcription (STAT), mitogen-activated protein kinase (MAPK), TNF- α , nuclear factor kappa B (NF- κ B), TNF- α , Nod-like receptor family proteins (NLRP), TLR, and mTOR pathways. Additionally, it inhibits the myeloperoxidase enzyme (MPO) and certain proinflammatory cytokines (IL-6, IL-1 β).^[49,50] Several authors have discovered that the rhizome's gingerols and shogaols lower hepatic markers of inflammation by inhibiting NF- κ B activity after consuming a high-fat meal.^[51] TNF-alpha suppression alters the inflammatory response and results in downregulated NF- κ B signaling. The oral treatment of gingerol, a bioactive component of ginger, boosted IL-10 and lowered the levels of cytokines (IL-1beta, IL-6), TNF-alpha, and NF- κ B (p65) in an animal model of mice with ulcerative colitis caused by dextran sulfate sodium. It also decreased the activities of monocyte chemoattractant protein-1 (MCP-1) and cyclooxygenase-2 (COX-2).^[49] 6-Shogaol, a bioactive substance found in dried ginger, has anti-inflammatory properties. Several studies have observed that it increases the expression of nuclear factor (erythroid-derived 2)-like 2 (Nrf-2) and heme oxygenase (HO-1) in a mouse model of DDS-induced colitis. It has also been shown to decrease the expression of TNF-alpha, IL-1beta, and IL-6.^[7,52] However, there are currently limited and often contradictory findings because Van Tilburg et al. conducted a pilot research with 45 IBD patients.^[53] discovered that ginger had no beneficial effects in comparison to a placebo group. By decreasing NF- κ B, which in turn decreases the production of cytokine genes, ginger reduces inflammation.^[7,54] According to multiple publications, ingesting ginger plus metformin in



liposomes for 21 days lowers TNF- α and IL-22 levels.^[55] These results imply that ginger's bioactive components might provide an alternative method of psoriasis treatment.

MATERIALS AND METHODS

This review focuses on the phytochemical components of ginger, primarily 6-gingerol, 6-shogaol, and zingerone and their role in modulating oxidative stress and inflammatory pathways.

Data Sources and Search Strategy: The literature review is conducted by searching major electronic databases for peer-reviewed articles

RESULTS AND DISCUSSION

Phytochemistry

According to phytochemical study, the ginger rhizome includes several physiologically active chemicals with medicinal properties.^[56,57] Essential oils, phenolic chemicals, flavonoids, proteins, carbohydrates, alkaloids, glycosides, saponins, steroids, terpenoids, and tannin are said to be the primary phytochemical groups present in *Z. officinale*.^[58]

Pharmacological significance

Ginger and its main ingredients are known to have positive therapeutic qualities in addition to their culinary application.^[8,56] Their effectiveness in treating diabetes, obesity, diarrhea, allergies, pain, fever, rheumatoid arthritis, inflammation, and different types of cancer has been substantiated by several pre-clinical investigations.^[5,59] Ginger's physiologically active components have been successfully used in animal models to treat tumors that have been created in the intestine, breast, ovaries, pancreas, liver, central nervous system, and cardiovascular diseases.^[60] Because of their capacity to prevent the oxidation of different free radicals and the generation of nitric oxide, ginger and its metabolites have been acknowledged as powerful antioxidants.^[61,62]

Effect on cardiac system

Numerous vascular and cardiac conditions, such as renal failure, CHF, IHD, CHD, and stroke, are directly caused by elevated blood pressure, or hypertension. Many herbal remedies target the heart and other abnormal cardiac conditions directly. *Zingiber officinale* is among the herbal remedies



mentioned by Acharya Charak and Sushruta as having "Hridya," or action on the heart (helpful in treating a range of cardiac diseases).^[63] Ginger's heart muscle-stimulating properties help boost blood flow throughout the body. Theoretically, increased blood flow promotes cellular metabolism, which reduces tension and cramping. Additionally, it lessens cardiac strain and blood pressure. Ginger's antioxidant properties are still another advantage. Umesh Bhandari, Neeraj Chaudhary, and K.K. Khanna have provided a thorough understanding of the antioxidant defense role against isoproterenol-induced oxidative cardiac injury in rats.^[64]

Ginger's Antioxidant activity

It has been demonstrated that the development of many chronic diseases is significantly influenced by the overproduction of free radicals, such as reactive oxygen species (ROS).^[65] Ginger's antioxidant activity was assessed in vitro using the ferric-reducing antioxidant power (FRAP), 2,2-diphenyl-1-picrylhydrazyl (DPPH), and 2,2'-azinobis-(3-ethylbenzothiazole-6-sulfonic acid) (ABTS) techniques. Compared to fresh, stir-fried, and carbonized ginger, dried ginger has 5, 2, and 1, 1 times as much phenolic chemicals, respectively. The following traits were typically seen in the antioxidant activity of different gingers: Ginger that has been dried, stir-fried, carbonized, and then fresh.^[66] Furthermore, evidence from FRAP, oxygen radical absorbance capacity, and cellular antioxidant activity assays showed significant antioxidant activity in a polyphenol-rich fraction of the dried ginger powder.^[67] Moreover, the kind of extraction solvent employed may have an effect on ginger's antioxidant activity. While an aqueous extract of ginger demonstrated strong free radical scavenging activity and chelating aptitude, an ethanolic extract demonstrated a notable antioxidant capacity and ferric-reducing ability.^[67] Ginger extract shown antioxidant qualities in human chondrocyte cells, where interleukin-1 induced oxidative damage.^[7] It reduced lipid peroxidation and reactive oxygen species formation while increasing the production of antioxidant enzymes. In stressed rat heart homogenates, ginger extract reduced the amount of malondialdehyde (MDA), which is linked to lipid peroxidation.^[68] To fight the free radicals that lead to oxidative stress in cells, antioxidants are commonly used. Antioxidant compounds can be made from natural resources, such as plants. Plants possess antioxidant qualities due to the presence of flavones, isoflavones, flavonoids, anthocyanin, coumarin lignans, catechins, and isocatechins.^[69] *Z. officinale* has been shown in numerous studies to exhibit antioxidant action against a variety of free radicals. The main ingredients in ginger, including



zingerone, shogaols, and gingerols, have potent antioxidant qualities.^[56] Its primary purpose is to prevent the production of reactive oxygen species by an enzyme known as xanthine oxidase.^[70] Through a mechanism that protects the smooth muscle of the gut from oxidative stress, gingerone has been demonstrated to protect in vitro DNA from oxidative damage brought on by ROS produced by stannous chloride.^[71] These substances greatly enhance ginger's antioxidant defense by scavenging DPPH radicals.^[67]

Anti-inflammatory and immunomodulatory activities

The pathogenesis of several diseases, such as atherosclerosis, cancer, diabetes, rheumatoid arthritis, and aging, is significantly influenced by chronic inflammation in particular.^[72] Ginger and its numerous active components have long been shown to have anti-inflammatory qualities in studies.^[7] At first, it was believed that ginger's capacity to inhibit the synthesis of prostaglandins and leukotrienes was the main factor responsible for its anti-inflammatory effects.^[54] Both fresh ginger, which is mostly composed of gingerols, and dried ginger extracts, a major source of shogal, have been demonstrated to prevent the production of prostaglandin E2 (PGE2) brought on by lipopolysaccharide (LPS).^[73]

CONCLUSION

Ginger (*Zingiber officinale*) has well-established anti-inflammatory and antioxidant qualities, which are mostly due to its bioactive components, which include zingerone, shogaols, and gingerols. Rheumatoid arthritis, inflammatory bowel disease, and cardiovascular problems can all benefit from these substances' ability to control important inflammatory mediators and oxidative stress pathways. More thorough clinical trials are necessary to confirm its effectiveness, establish the ideal dosage, and guarantee safety, even though preclinical research appears encouraging. Ginger is a promising supplementary treatment for disorders linked to inflammation, which is in line with the growing interest in plant-based therapies.

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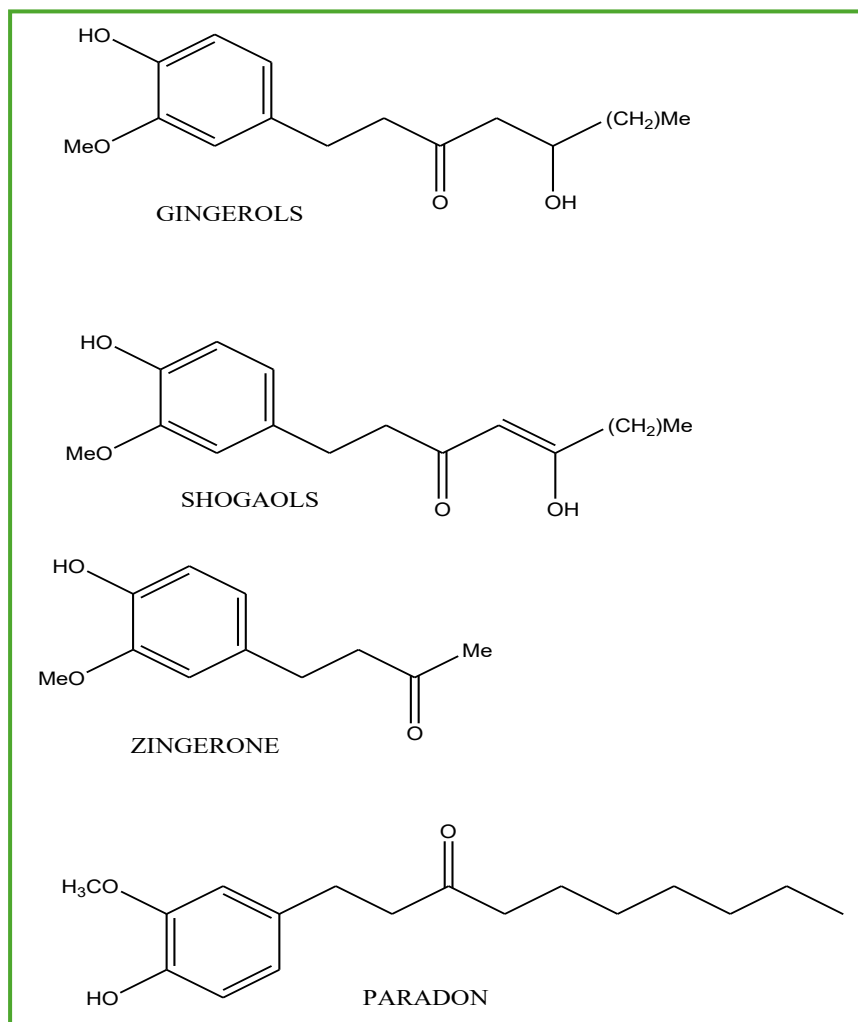
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Every chemical is listed in the table according to its chemical class

Table 1. Active phytochemical constituents of *Zingiber officinale*.

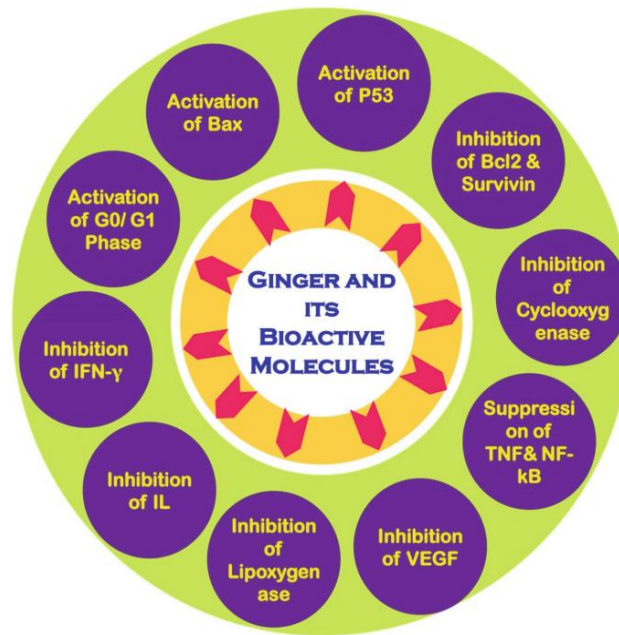
CHEMICAL CLASS	NAME OF PHYTOCOMPOUNDS
Vitamin	Vit. B5, B6, E.
Sesquiterpene	Zingiberene, β -Sesquiphellandrene, β -Besabolene
Non-volatile pungent scaffolds	Gingerols (GN), Shogaols, Paradols, Zingerone
Mineral	Iron, Magnesium, Phosphorous, Calcium, Sodium
Monoterpenoid	β -phellandrene, cineol, and citral

Chemical Structures of Ginger-Derived Bioactive Constituents.

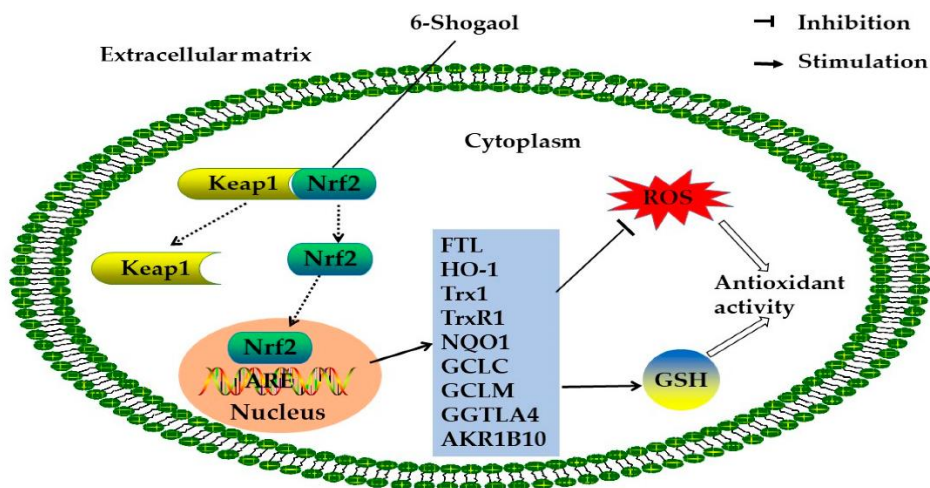


Figure_1

'Therapeutic Role of Ginger in Various diseases'



Figure_2
'Ginger and it's bioactive components'



Figure_3
'General mechanism'



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FORMULATION AND EVALUATION OF A READY-TO-MIX POLYHERBAL MIXTURE

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ABSTRACT

The present study was aimed at the development and evaluation of a ready-to-mix polyherbal skin mask powder using selected medicinal plant materials, namely green tea powder (*Camellia sinensis*), licorice root powder (*Glycyrrhiza glabra*), tulsi powder (*Ocimum sanctum*), aloe vera dried gel powder (*Aloe barbadensis miller*), rose petal powder (*Rosa species*), and neem powder (*Azadirachta indica*). These herbal ingredients were selected based on their well-documented antioxidant, anti-inflammatory, antimicrobial, soothing, and skin-protective properties. Green tea is rich in polyphenols and provides strong antioxidant and anti-aging effects. Licorice root is known for its skin-brightening, anti-inflammatory, and soothing activities. Tulsi and neem possess significant antimicrobial and anti-inflammatory properties, making them suitable for acne-prone and irritated skin. Aloe vera dried gel powder acts as a natural moisturizer and skin-soothing agent, while rose petal powder contributes to skin toning, refreshing, and calming effects. All the herbal powders were properly dried, powdered, sieved, and blended in suitable proportions to obtain a uniform, free-flowing, ready-to-mix formulation. The developed formulation is intended to be mixed with water or rose water before application to form a smooth paste for topical use. The polyherbal combination is expected to provide synergistic effects such as cleansing, soothing, brightening, moisturizing, and protection of the skin from oxidative stress. Thus, the formulated herbal skin mask powder represents a natural, safe, and effective cosmetic preparation without the use of synthetic chemicals and it has potential application in routine skincare for maintaining healthy and radiant skin.

KEYWORDS

Antioxidant activity, Anti-inflammatory activity, skin brightening, Moisturizing agent, Acne management, skin soothing

INTRODUCTION



Everyone wants to have fair and attractive skin. Today, acne, blackheads, pimples, dark circles are common among young people and people suffering from them. According to Ayurveda, skin problems are usually due to impurities in the blood. Toxins that accumulate in the blood from improper diet and lifestyle cause skin related diseases. Various herbs and medicines are prescribed in Ayurveda to purify the blood. The herbal paste applied to the face to treat acne, pimples, scars, scars and pigments is known as "Mukhalepa" in Ayurveda. The process of spreading this mixture of herbs on the face is known as "Mukhalepana". This beauty treatment is popular as a facial ^[1]. Various skin types require various kinds of herbal face packs. Homemade natural face packs and masks make way for smooth, healthy and silky skin. In Ayurveda, the herbal paste applied to the face is known as "Mukhalepa" for treating acne, pimples, wounds, stain and pigments "Mukhalepana" is the process of smearing a herbal mix on face. This therapy is now popularly termed as facial ^[2].

From the ancient period of time, people are of the use of plants for healthy, glowing and beautiful skin. Cosmetic are used to clean, beautify and promote attractive appearance of the skin, hair, lips. Cosmetics are commercially available products that are used to improve the appearance of the skin by action of cleansing , beautifying, promoting attractiveness. Face skin is the major part of the body, which indicates the health of an individual ^[3]. A balanced nutrition containing amino acids, carbohydrates and lipids are required for the skin it clear, glossy, and healthy. Women are very conscious about their beauty and took special care of their special care of their specific skin type ^[4].

Due to increased pollution and global warming the quality of air is deteriorated and harmful UV rays are causing much more damage to skin. In this time formulation of herbal face pack is like boon for skin healing. Different types of skin need different types of herbal face packs. The herbal face packs which are mentioned in ayurveda help women to get rid of wrinkles, dark circles, pimples and acne. Herbal face packs increase the fairness and smoothness of skin. We can derive the maximum benefits of herbal face packs by using them according to our skin type. These face packs increase skin glow and are best ayurveda treatment to increase fairness ^[5].

Face mask will be helpful in tightening the skin on the face and help in avoiding the appearing of scars and dark marks. After 15 to 20 minutes the face mask can be removed with Luke warm water as it helps in smooth removal of face pack. The herbal face packs are helps to reduce wrinkles, pimples, acne, blemishes, pustules, nodules and also dark circles. It is also helps to increases the fairness and smoothness of the facial skin ^[6].



Different types of herbal face packs are suitable for various skin types, such as oily or dry skin. The herbal face pack acts by improving blood circulation in the veins of skin but the effect of facial face packs is generally temporary, so for regular glow it should be used 2-3 times a week ^[7].

The skin functions as a protector from exposure to UV rays. Exposure to UV rays for a long time can often cause skin problems, namely hyperpigmentation. Hyperpigmentation is a condition of uneven pigmentation in skin, and an increase in excess melanin production which causes darkening or an increase in skin

color^[8].

The formulation process began with the selection of ingredients known for their beneficial properties. Liquorice (*Glycyrrhiza glabra*) serves as the primary active ingredient due to its anti-aging, UV protective, and skin-brightening effects. Rose powder adds moisturizing and cooling effects while Neem is treating the anti-inflammatory effect. Each ingredient contributes to the overall effectiveness of the face pack, ensuring a synergistic approach to skin rejuvenation^[9].

Different types of herbal face pack are used for different skin types. Herbal face pack helps reduce wrinkles, acne, acne and dark circles. And increase the smoothness and smoothness of the skin. It also helps a person to develop self-confidence. Ayurveda is a very effective and efficient way to achieve this goal^[10].

Aloe vera has many active compounds that help to reduce acne, soothe the skin, keep it hydrated, and heal skin problems. The dried aloe vera used in the face pack also gives these benefits to the skin ^[11].

There are different types of facial masks described in Ayurveda that have nutritional, healing, cleansing, astringent and antiseptic properties. Ayurveda is the science of life which deals with maintenance of health of healthy persons and cure of ailing humanity as its main ambition^[12].

Herbal face packs are nowadays being used on a large scale, due to the various benefits of them over chemical based packs. They are non-toxic, non-allergic, and non-habit forming. They are natural in every aspect, having larger shelf-life.

Green tea has natural compounds that help reduce acne, control excess oil, and protect the skin. The dried green tea used in the face pack also gives these benefits and keeps the skin healthy^[13].

Tulsi has natural compounds that help reduce acne, control oil, and protect the skin. The dried tulsi powder used in the face pack also gives these benefits and keeps the skin healthy ^[14].



Herbal face packs preparations are applied on the face in the form of liquid or pastes and allowed to dry and set to form film giving lightening, strengthening and cleansing effect to the skin. The warmth and tightening effect produced by application of the face pack produces the stimulating sensation of a rejuvenated face, while the colloidal and adsorption clays used in these preparations remove the dirt and grease from the skin of the face. Herbal face packs are used for the purpose like deep cleansing, astringents, stimulating, tanning, hydrating and nourishing^[15].

Advantages of herbal facial mask:

- 1.Natural and safe
- 2.Chemical free formulation
- 3.Cleansing, moisturizing,soothing, and brightening effects
- 4.Antioxidant properties
- 5.Anti-inflammatory action: Reduces redness, irritation and inflammation
- 6.Antimicrobial activity: Acne, pimples, and skin infections
- 7.Skin brightening and glow
- 8.Moisturizing and hydration: Prevents dryness and keeps skin soft
- 9.Eco-friendly and Biodegradable
- 10.Easy to store (Powder form): Longer shelf life compared to liquid products, less microbial contamination.

Disadvantages of herbal facial mask:

- 1.Short shelf life after mixing
- 2.Possibility of allergic reactions
- 3.Slower results
- 4.Less standardization
- 5.Sometimes our skin displays signs of irritability and redness.

OBJECTIVES

1. To formulate a safe and effective ready-to-mix herbal facial pack using natural ingredients.
2. To evaluate the anti-acne and anti-pimple properties of the herbal formulation.
3. To study the cleansing action of the face pack in removing dead skin cells and impurities.



4. To assess the oil control ability of the formulation for maintaining balanced skin.
5. To evaluate the skin brightening and glow-enhancing effect of the face pack.
6. To study the effect of herbal ingredients on reducing scars, marks, and pigmentation.
7. To evaluate the anti-aging properties, including reduction of wrinkles and fine lines.
8. To assess the improvement in skin texture, elasticity, and overall appearance.
9. To ensure the safety and stability of the formulation without using synthetic preservatives^[16].

MATERIALS AND METHODS

All the herbal ingredients used in the present work i.e., rose petal, tulsi powder, green tea powder, neem, licorice root powder, aloe vera was purchased from local market in the form of dried powder.

A.GREEN TEA:

Biological source: The biological source of green tea is the leaves and leaf buds of the evergreen plant *Camellia sinensis*, belonging to the theaceae family, native to asia, with its health benefits largely attributed to its rich polyphenols, particularly catechins like EGCG, which aren't fully oxidized during processing, making it distinct from black tea.

Green tea is touted to be one of the healthiest beverages on the planet. It's loaded with antioxidants that have many health benefits. Tea is rich in polyphenols, which are natural compounds that have health benefits, such as reducing inflammation and helping to fight cancer. Contains healthy bioactive compounds. Green tea does more than just keep you alert; it may also help boost brain function. Increases fat burning. Antioxidants may lower the risk of some cancers. May protect the brain from aging and reduce bad breath. May help to prevent cardiovascular disease. May help you lose weight. May help you live longer^[17].

Scientific name: *camellia sinensis*

Plant type: An evergreen shrub or small tree, usually kept trimmed for easy harvesting.

Family: Theaceae

Origin: China, but now cultivated across Asia.



Processing: Unlike black tea, green tea leaves are minimally processed[not withered or oxidized], preserving more of their natural compounds, especially catechins.

Bioactive Compounds: Rich in antioxidants, particularly polyphenols like flavonoids and catechins [EGCG,EC,ECG], caffeine, and other substances that contribute to its therapeutic effects.

Chemical constituents: Green tea in facial sheet masks primarily utilizes polyphenols, specifically catechins like epigallocatechin gallate (EGCG), which provide potent antioxidant, anti-inflammatory, and anti-aging benefits to fight free radicals, reduce UV damage, and soothe irritation. Other key components include caffeine to reduce puffiness, tannins to tighten pores, and nutrients like vitamins E and C.

Active components of green tea in masks:

Polyphenols [Catechins]: The main active compounds, particularly Epigallocatechin Gallate[EGCG], act as powerful antioxidants that repair DNA damage from UV rays and neutralize free radicals.

Caffeine: Acts as a stimulant to increase circulation and acts as a vasoconstrictor to reduce facial puffiness and dark circles.

Tannins: Function as natural astringents, which help to shrink pores, control excess oil production, and tighten the skin.

Theanine: An amino acid with anti-inflammatory properties that helps soothe irritated or acne-prone skin.

Vitamins and Minerals: Rich in vitamins A,C,E, and B-complex, which aid in skin nourishment, collagen maintenance, and overall skin health.

Chlorophyll: Provides detoxification properties to the skin. These compounds are often extracted into a glycerite[using glycerin] or formulated as a Concentrated extract in masks to improve elasticity, reduce acne, and enhance radiance^[18].

Skin Benefits of Green Tea:



Green tea offers significant skin benefits, primarily driven by its high concentration of polyphenols (specifically EGCG), which act as powerful antioxidants to Fight free radicals, reduce inflammation, and combat premature aging. It helps minimize acne by controlling sebum production, reduces under-eye puffiness, and hydrates the skin.

Fights Acne: Green tea possesses antibacterial properties that help unclog pores, cleanse the skin, and reduce sebum production, making it effective for acne-prone skin.

Anti-Aging: It protects against UV damage, repairs skin cells, and maintains collagen, which reduces fine lines, wrinkles, and improves skin elasticity.

Reduces Inflammation & Redness: The anti-inflammatory properties of green tea help calm irritation, soothe skin conditions like eczema, and reduce redness^[19].

Brightens & Hydrates: It provides essential moisture to the skin, helping it look more radiant and improving overall complexion.

Reduces Puffiness: The caffeine in green tea helps shrink blood vessels, effectively reducing under-eye bags and dark circles.

Provides UV Protection: Polyphenols in green tea help protect the skin from damage caused by sun exposure^[20].

Benefits of green tea:

Moisturing and skin texture improvement:

In a clinical study, cosmetic formulations containing green tea[camellia sinensis] with 6% extract were applied topically to human skin.

Results showed that:

Skin moisture increased over 15-30 days.

Transepidermal water loss[TEWL] reduced.



Skin roughness decreased.

This indicates a prolonged moisturizing effect and improved skin surface condition with green tea-containing cosmetics.

Anti-inflammatory and photoprotective effects:

Research shows that green tea polyphenols, especially EGCG, can:

Reduce UVB-induced skin damage.

Protect against oxidative stress and immune suppression.

Decrease inflammatory responses.

These results support green tea as an antioxidant and protective skin care agent^[21].

Clinical facial application study:

A split- face, placebo-controlled clinical trial evaluated green tea extract encapsulated in chitosan microparticles applied topically on the face.

Results included:

Improved skin elasticity.

Reduced skin dullness.

Less visible facial wrinkles.

There were no signs of irritation, showing safety and cosmetic benefit.

Acne Reduction evidence:



A systematic review of randomized clinical trials found that topical green tea extract significantly reduced acne lesions [both inflammatory and non-inflammatory] when applied directly to the skin. This shows green tea's potential in acne management when used in skin care products.

Anti-Aging and photoaging benefits:

Antioxidant action against UV induced cellular damage.

Reduced erythema and DNA damage.

Protective effects in topical applications at certain concentrations.

This supports the inclusion of green tea in anti-aging and protective skin care formulation^[22].

B. LIQUORICE ROOT POWDER:

Liquorice root powder (often referred to as Mulethi powder in Ayurveda) is a natural skincare ingredient derived from the root of the glycyrrhiza glabra plant. It is widely used to treat skin pigmentation, hyperpigmentation, acne, and inflammation.

Liquorice is one of the most used herbal plants in foods, in medicinal forms, and substantially researched on a worldwide scale. It was used as traditional and complementary medicine against innumerable ailments including allergies, liver toxicity, gastric ulcer, lung diseases, skin disorders, oral health problems including allergies, liver toxicity, gastric ulcer, lung diseases, skin disorders, oral health problems including tooth decay, and inflammation^[23].

Glycyrrhizin has been found to exhibit natural UV (ultraviolet) radiation blocking properties. When applied topically, glycyrrhizin creates a protective shield on the skin's surface. This shield operates by either deflecting or absorbing a portion of the incoming UV radiation, thus mitigating its potential to penetrate and harm the underlying skin layers. In the annals of Ayurvedic medicine, the traditional healthcare system of India, liquorice found a prominent role^[24].

If you suffer from hyperpigmentation, a condition in which patches of skin become darker than the surrounding skin due to increased deposition of melanin in these Areas, liquorice root can return the skin to a lighter color when used on the dark area every day. If you suffer from melasma (also known as



pregnancy mask), this is a great natural solution to lighten your skin after birth. Liquorice root is said to have a positive effect on the skin and help reduce inflammation. Glycyrrhizin found in the bark can reduce redness, irritation and swelling and is used to treat skin conditions such as atopic dermatitis and eczema. Liquorice root helps renew the skin's collagen and produce elastin; Both of these are essential to keep our skin soft, supple and baby-soft. Not only that, walnuts also help store Hyaluronic acid, a sugar molecule that can hold up to Times its own weight in water, keeping the skin plump and plump^[25].

Biological Source and Characteristics:

Botanical Name: Glycyrrhiza glabra Linn.

Family: Fabaceae (or Leguminosae).

Common Names: Mulethi (Hindi), Yashtimadhu, Liquorice, Sweet wood.

Plant Part Used: Roots and underground stems (stolons).

Geographical Distribution: Native to the Mediterranean region, Asia, and the Middle East, with major cultivation in India, China, Spain, and Iran.

Active Compounds of Liquorice root powder:

Glabridin: A potent antioxidant that helps inhibit tyrosinase (the enzyme responsible for melanin production), which aids in lightening dark spots, acne marks, and sun damage.

Glycyrrhizin: A triterpenoid compound with anti-inflammatory, antimicrobial, and soothing properties.

Licochalcone A: A flavonoid that helps protect the skin from UV damage^[26].

Benefits for Skin:

Reduces Hyper-pigmentation: It inhibits melanin production, making it effective for treating dark spots, sun tan, and melasma.



Soothes Inflammation: It helps reduce skin irritation, redness, and sensitivity, acting similarly to hydrocortisone, which makes it beneficial for acne, eczema, and psoriasis.

Antioxidant Protection: It fights free radicals that cause premature aging and damage from UV rays.

Brightens Skin Tone: Regular use promotes a more even, glowing, and radiant complexion.

Acne Control: Its antimicrobial and anti-inflammatory properties help reduce acne breakouts^[26].

Benefits of Liquorice Root Powder for Skin:

Anti-inflammatory and soothing activity

Previous studies have reported that licorice root contains glycyrrhizin and related compounds which show significant anti-inflammatory activity. These compounds help in reducing skin redness, irritation, and swelling. Due to this property, licorice root has been widely studied and used in formulations meant for sensitive and irritated skin.

Skin-Lightening and Anti-Pigmentation Effect

It has been reported in earlier studies that glabridin and liquiritin present in licorice root inhibit the tyrosinase enzyme and reduce melanin synthesis. This action helps in decreasing hyperpigmentation, dark spots, and uneven skin tone. Therefore, liquorice root is considered an effective natural skin-brightening agent.

Antioxidant Activity

Previous research has shown that licorice root is rich in flavonoids and phenolic compounds which possess strong antioxidant activity. These antioxidants protect the skin from free radical damage and oxidative stress, thereby helping in the prevention of premature aging and maintaining healthy skin^[27].

Antimicrobial Activity

Some studies have reported that liquorice root exhibits antimicrobial activity against certain bacteria and fungi. This property supports its use in skincare formulations for acne-prone skin and in preventing minor skin infections.



Skin-Protective and Healing Effect

Earlier studies have indicated that liquorice root helps in protecting the skin barrier and supporting skin healing due to its combined anti-inflammatory and antioxidant properties. This makes it useful in formulations designed for damaged or stressed skin.

Traditional and Cosmetic Use

Previous literature also mentions the long history of licorice root use in traditional medicine and herbal cosmetics for improving skin complexion, soothing the skin, and maintaining overall skin health. This traditional use is supported by modern scientific studies on its active constituents^[28].

C.TULSI POWDER FOR SKIN:

Tulsi powder, derived from the dried leaves of the holy basil plant (*Ocimum Sanctum/Ocimum tenuiflorum*), is a potent, nutrient-rich Ayurvedic herbal powder with significant benefits for skin health. Revered for its adaptogenic, antibacterial, antifungal, and anti-inflammatory properties, it helps in reducing acne, soothing irritation, controlling oil, and fighting signs of aging.

Ocimum tenuiflorum, commonly known as holy basil, tulsi or tulasi, is an aromatic perennial Plant in the family Lamiaceae. It is native to the Indian subcontinent and widespread as a Cultivated plant throughout the Southeast Asian tropics. Tulsi powder is basically dried and ground tulsi leaves, and it's super versatile. You can mix it with honey, rose water, or yogurt to create a fresh face mask. Some folks even blend it with fuller's earth (also known as Multani mitti) for a clay mask that helps draw out oil and toxins. The **tulsi powder benefits for skin** include exfoliation, reduction in acne scars, and improved skin texture^[29].

Biological Source

Kingdom: Plantae

Division: Magnoliophyta

Order: Lamiales



Family: Lamiaceae

Genus: Ocimum

Species: O.tenuiflorum

Botanical Name:- Ocimum tenuiflorum

Active Compounds of Tulsi Powder:

The primary active ingredients in tulsi leaves that offer skin benefits include:

Eugenol: The most potent component in Holy Basil, it has high antiseptic and anti-inflammatory properties, making it excellent for treating acne, rashes, and reducing skin swelling.

Ursolic Acid: This compound possesses strong anti-inflammatory effects and helps in calming skin irritation and reducing acne, pimples, and eczema.

Rosmarinic Acid: A powerful phenolic compound with antioxidant properties that helps protect the skin from free radicals and damage.

Linalool: Known for its antimicrobial properties, it helps combat acne-causing bacteria.

Camphor: Provides a soothing, cooling effect on inflamed skin.

Other Components: Flavonoids (orientin, vicenin), tannins, and saponins also contribute to its antioxidant and antimicrobial properties^[30].

Benefits of Tulsi powder:

Acne Treatment: Fights acne-causing bacteria, reduces excess oil, and cleanses pores.

Anti-Aging: Antioxidants (especially eugenol) fight free radicals, reducing fine lines, wrinkles, and maintaining skin firmness.

Skin Brightening: Reduces pigmentation, dark spots, and evens out skin tone.

Soothing: Calms inflammation, redness, and itching associated with skin conditions like eczema.



Anti-inflammatory: Tulsi has **anti-inflammatory properties**, which help in **soothing irritated and inflamed skin**.

Detoxification: It supports **detoxification of the skin**, removing toxins and promoting a healthy complexion.

Antibacterial: It has **antibacterial properties**, which help in **preventing and treating acne and blackheads**.

Sensitive skin: However, it should be used in moderation, especially for **sensitive skin**, to avoid irritation^[30].

D.NEEM POWDER:

Neem powder is biologically sourced from the dried and ground leaves, bark, or seeds of the neem tree, *Azadirachta indica* A.Juss. It belongs to the mahogany family *Meliaceae*, and is native to India and Southeast Asia. Neem is anti-inflammatory, antiseptic and highly beneficial for oily and acne-prone skin. An anti-acne effect is due to anti-microbial, anti-inflammatory and anti-oxidant activities of different chemical constituents. The phytochemical components of neem were reported to include carotenoids, phenolic acids, and flavonoids that might provide high antioxidant activity, leading to potential activities in skin anti-aging. Neem's benefits for skin care stem from its being antifungal and antibacterial. This helps it cleanse the skin cells of irritants and dead skin cells that may have otherwise formed pus and inflamed the facial skin. Commonly known as acne, these red-colored protrusions on the facial skin may become painful if not treated early^[31]. Also counted among the neem benefits of skincare is how it effectively removes acne and pimple marks to help you have a clear and blemish-free appearance.

Neem is anti-inflammatory, antiseptic and ideal for oily and acne-prone skin. It has anti-acne effects thanks to the antimicrobial, anti-inflammatory and antioxidant activities of various chemical components. In March 2020, false claims promoting the use of neem leaves to treat COVID-19 spread on social media in many countries in Southeast Asia and Africa. The Malaysian Ministry of Health has outlined myths regarding the use of leaves in COVID-19 treatment and warned of health risks associated with excessive consumption of leaves. No evidence that neem leaves are effective in treating COVID 19^[32].



Kingdom: Plantae

Division: Angiosperms

Class: Dicotyledons

Order: Sapindales

Family: Meliaceae

Genus: Azadirachta

Species: Azadirachta indica

Benefits of Neem powder:

Anti-Microbial : Has strong **anti-microbial properties**, which help kill acne-causing bacteria.

Anti-inflammatory: Shows **anti-inflammatory action**, reducing redness and swelling of pimples.

Antioxidants: Contains **antioxidants** that protect skin from damage.

Antiseptic: Acts as an **antiseptic**, helping to heal wounds and prevent infections.

Acne Treatment: Controls **excess oil (sebum)**, making it ideal for oily and acne-prone skin^[33].

E. ROSE PETALS POWDER:

Rose petals are obtained from the flowers of *Rosa damascena* and *Rosa centifolia* (Family: Rosaceae).

To make rose petal powder at home you shall need 10-15 roses. Remove the petals from the roses and place them in a bowl. Wash the petals nicely to remove any dust or dirt particles trapped in them and spread them on the tray. After this, leave them in a safe place to let them dry for about 4-5 days.

Vitamins K, C, and B, as well as the antibacterial characteristics of rose petals, are abundant in rose petal powder. Antioxidants are also present in good amounts^[34].

Kingdom: Plantae



Subkingdom: Tracheobionta (Vascular plants)

Division: Magnoliophyta (Angiosperms)

Class: Magnoliopsida (Dicotyledons)

Order: Rosales

Family: Rosaceae

Genus: Rosa

Species: Rosa damascene, Rosa centifolia

Benefits of Rose Petal Powder :

Prevents signs of Aging: Rose petal powder contains antioxidants that help neutralize free radicals, which can cause damage to the skin and lead to premature ageing. Regular use of rose petal powder can help reduce the appearance of fine lines, wrinkles, and age spots, promoting a more youthful complexion.

Cleanses the skin: Rose petals mixed with water have been used for centuries for bathing. It is because rose petals have cleansing properties and they provide a decent aroma to the body. Rose petal powder offers the same benefits and hence can be used as a cleanser.

Reduces redness on the skin: According to a study by NCBI, Rose petal powder has anti-inflammatory properties that can help soothe and calm irritated or red skin. It can be particularly beneficial for individuals with sensitive or rosacea-prone skin, as it helps reduce redness and inflammation, promoting a more even skin tone^[35].

Prevents skin Damage: The antioxidants present in rose petal powder help protect the skin from damage caused by environmental pollutants and harmful UV rays. They act as a shield against oxidative stress, minimizing the risk of skin damage and maintaining a healthier complexion.



Moisturises skin: The natural oils present in rose petals help lock in moisture and provide hydration to the skin. It is one of the top rose powder benefits for skin. Rose petals powder can be used in facial masks, cleansers, or tones to help moisturize and nourish the skin, making it softer and more supple.

Reduces Pigmentation: The natural compounds found in rose petals, such as vit C, can help fade pigmentation and dark spots on the skin. Regular application of rose petal powder can assist in lightening these areas and achieving a more uniform complexion^[36].

Exfoliates skin: one of the rose powder benefits for the skin is its exfoliating properties that aid in the removal of dead skin cells and unclogging of pores. Regular exfoliation with rose petal powder can help improve skin texture, promote cell turnover, and reveal a smoother, more radiant complexion.

Even Tones the skin: Rose petal powder has a balancing effect on the skin, making it beneficial for evening out uneven skin tone and discoloration. Regular use can help reduce the appearance of blemishes, hyperpigmentation, and redness, resulting in a more uniform complexion.

Removes Tan: The natural properties of rose petal powder can help lighten and remove tan from the skin. It assists in reducing the darkening of the skin caused by sun exposure and help restore a more even skin tone.

Provides Soothing Effects: The aroma of rose petals is very soothing that provides calming effects. It can act as a stress, buster, calm mood, and promote overall well-being.

Boosts Collagen: Rose petal powder is a great source of vit A and C. Hence it promotes collagen production in skin that delays early signs of aging. It also makes skin smooth and supple keeping away any fine lines and wrinkles. Additionally, Vit C helps to the skin and give it a smooth texture.

Reduces Sebum: Rose petal also has astringent properties that clean the pores from the depth and removes accumulated dirt, oil, and sebum. Therefore it is great for oily skin. It increases hydration and increases absorption of nutrients in the skin^[37].

F.ALOE VERA:

Aloe vera is an excellent moisturizer made for the skin. Aloe vera rejuvenates the skin, hydrates this and keeps the skin layer looking fresh all the time. Aloe vera has anti-microbial properties that make it ideal



for acne and acne. Aloe vera powder contains several nutrients such as glycerin, sodium palmate, sodium carbonate, sodium palm kemelate, sorbitol, etc^[37].

Aloe Barbadensis has anti-microbial property rendering it ideal to deal with acne and pimples. Aloe Vera is a great moisturizer intended for a skin. Aloe Vera powder contains several nutrients like glycerine, sodium palmate, sodium carbonate, sodium palm kemelate, sorbitol. You can use aloe Vera to keep your skin clear and hydrated. This may be because the plant thrives in dry, unstable climates. To survive the harsh conditions, the plant's leaves store water. These water-dense leaves, combined with special plant compounds called complex carbohydrates, make it an effective face moisturizer and pain reliever^[37].

Aloe Vera (Aloe barbadensis) has cooling properties anti-inflammatory, sunburn or burnt skin. It has great moisturizer intended for a facial skin. It rejuvenates skin, hydrates and feels fresh and cool after applying to the facial skin. It is also having anti-microbial property and removes acne and pimples. Aloe vera gel is known as a cooling healer in Ayurveda. Its gel contains aloesin and aloin, compounds that can destroy melanin cells and prevent further pigment formation. This makes aloe helpful for lightening sunspots and pigmentation. Aloe is also deeply hydrating.

Kingdom: Plantae

Division: Angiosperms

Class: Monocotyledons

Order: Asparagales

Family: Asphodelaceae

Genus: Aloe

Species: Aloe vera

Benefits:



Hydrates and soothes all skin types (sunburn, dry skin). Aloesinin aloe breaks down existing melanin and inhibits new pigment, fading dark marks.

Wound Healing: Accelerates wound contraction and collagen synthesis.

Anti-inflammatory: Inhibits the cyclooxygenase pathway and reduces prostaglandin production, treating skin irritations.

Skin Care: Acts as a moisturizer and aids in reducing acne, psoriasis, and dermatitis.

Burns & Radiation: Effective at soothing radiation-induced burns and sun damage.

Other Potential Effects: Research indicates antitumor, antidiabetic, anti-viral, and laxative (via anthraquinones) properties^[38].

Procedure of Face Pack Formulation:

Weighing: All the required herbal powders for face pack preparation were accurately weighed individually by using digital balance. The quantity and compositions are listed in Table No.1.

Mixing: All these fine ingredients were mixed thoroughly by mixer to form a homogenous fine powder.

Sieving: Then this fine powder was passed through sieve, to get the sufficient quantity of fine powder.

Collection and storage: The powder mixture was collected and store in suitable plastic container and used for doing evaluation parameters^[42].

How to Apply Face Pack:

- 1.Take prepared face pack powder in a bowl as per the requirement.
- 2.Add water or rose water to mix it well and apply over the facial skin.
- 3.Cover the acne and blemishes spots.
- 4.Kept as it is for complete drying for 30 to 40 min.
- 5.Then wash the face with cold water^[42].

Table No.1: Ingredient list of formulation

Sr. No.	Ingredient	Quantity	Role
1.	Liquorice root powder	25g	Brightening ,Soothing
2.	Green tea powder	17g	Antioxidant
3.	Neem Powder	16.5g	Antibacterial
4.	Tulsi powder	16.5g	Antimicrobial
5.	Rose petal powder	10g	Cooling ,Calming
6.	Aloe vera powder	10g	Moisturizing ,soothing

Evaluation of Face Pack:

A. Organoleptic Properties: Organoleptic properties include its nature, colour, odour, texture, smoothness etc.

B. Physicochemical Properties: Physicochemical properties were determined including the pH, ash value, loss on drying, acid insoluble ash and water soluble ash.

1. pH: pH of the aqueous solution of formulation was measured by pH meter^[43]. The pH of effective herbal face packs is generally formulated to be neutral to slightly acidic, typically ranging between **5.5 and 6.9**.

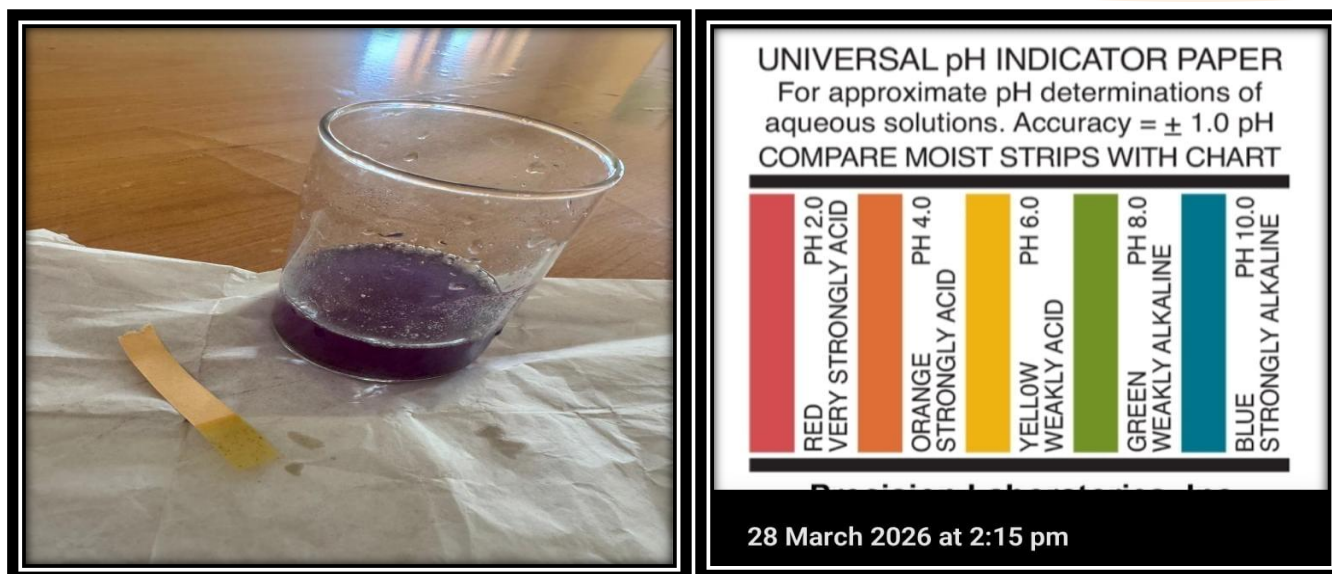


Figure No 1: PH

2. Ash Value: Ash value is a criterion to judge the identity or purity of the crude drug. Inorganic salts such as carbonates, phosphate, calcium, sodium, potassium are known as ash content^{[42][43]}. Place about 2-4g of the ground air-dried material, accurately weighed, in a previously ignited and crucible (usually of platinum or silica). Spread the material in an even layer and ignite it by gradually increasing the heat to 500-600°C until it is white, indicating the absence of carbon. Cool in a desiccators and weigh. If carbon-free ash cannot be obtained in this manner, cool the crucible and moisten the residue with about 2 ml of water or a saturated solution of ammonium nitrate R. Dry on a water-bath, then on a hot-plate and ignite to constant weight. Allow the residue to cool in suitable desiccators for 30 minutes and then weigh without delay. Calculate the content of total ash in mg per g of air-dried material^[43]. The ash value of herbal face packs generally indicates the inorganic content, with reported values usually falling within a range that suggests high-quality organic materials, often found around 0.8 to 3% for total ash in specific studies. The typical ash value for high-quality botanical materials or pharmaceutical-grade powder is in the range of 0.03%–0.07% by mass.

Weight of the empty crucible (x) = 214.975

Weight of the sample drug taken (y) = 2

Weight of the crucible +Ash [after complete incineration] (z) = 214.982

Calculation:

Weight of the ash= (z-x) g

$$= 214.982-214.975$$

$$= 0.007g$$

'y' g of crude drug gives (z-x)g of ash, 100g of the crude drug gives $100/y \times (z-x)$ g of the ash.

Total Ash value of the sample= $100 \times 0.007/2$

$$= 0.7/2 = 0.35$$



Figure No.2: Ash Value

3. Acid Insoluble Ash: Place about 2-4g of the ground air dried material, accurately weighed, in a previously ignited and tarred crucible (usually of platinum or silica). Spread the material in an even layer and ignite it by gradually increasing the heat to 500-600°C until it is white, indicating the absence of carbon. Cool in desiccators and weigh. If carbon-free ash cannot be obtained in this manner, cool the crucible and moisten the residue with about 2 ml of water or a saturated solution of ammonium nitrate R. Dry on a water-bath, then on a hot-plate and ignite to constant weight. Allow the residue to cool in suitable desiccators for 30 minutes and then weigh without delay^[42]. Many formulated herbal face

packs maintain a range for acid insoluble ash that is typically low, often reported in studies to be between 0.5% and 2.5%.

Calculate the content of total ash in mg per g of air-dried material.

Weight of the empty crucible= 37.66

Weight of the crucible+Ash= 37.69

Weight of the ash= 0.03

Calculation:

Similar to previous experiment. Weight of the residue='a'g(acid insoluble ash)

'y'g of the air dried drug gives 'a'g of acid insoluble ash, 100 g of the air dried drug gives $100 \times a/y$ g of acid insoluble ash.

Sample weight (y)= 2

g of acid insoluble ash= 0.03

Acid insoluble ash value of the sample= $100 \times a/y$

$$= 100 \times 0.03/2 = 1.5\%$$



Figure No.3: Acid Insoluble Ash

4. Water Soluble Ash: To the crucible containing the total ash, add 25 ml of water and boil for 5 minutes. Collect the insoluble matter in a sintered-glass crucible or on an ash less filter-paper. Wash with hot water and ignite in a crucible for 15 minutes at a temperature not exceeding 450°C. Subtract the weight of this residue in mg from the weight of total ash. Calculate the content of water-soluble ash in mg per g of air-dried material^[40]. The water-soluble ash value for herbal face pack formulations generally falls in the range of 2.0% to 5.0% w/w.

Calculation:

Similar to previous experiment. Weight of the residue='a'g(water soluble ash)

'y'g of the air dried drug gives 'a'g of water soluble ash, 100 g of the air dried drug gives $100 \times a/y$ g of water soluble ash.

Sample weight (y)= 2

g of water soluble ash= 0.06

water soluble ash value of the sample= $100 \times a/y$

$$= 100 \times 0.06/2 = 3\%$$

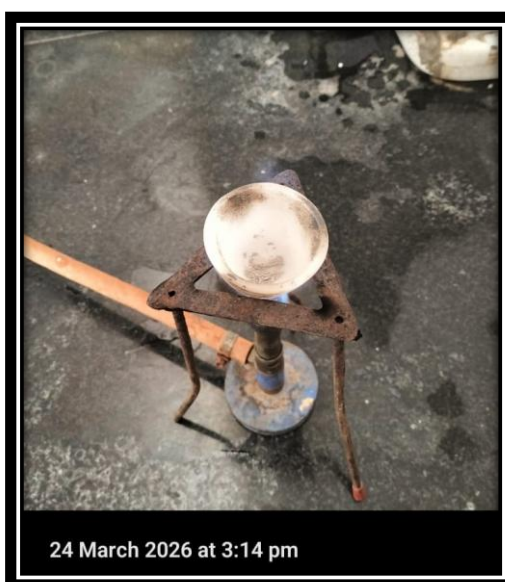


Figure No.4: Water soluble Ash

5. Loss On Drying: A method commonly used for moisture content determination is the loss-on-drying method, or LOD. It is used to specify many major quality specifications. This is based on the thermogravimetric principle, in which a substance is heated until no more weight is lost, that is, it is completely dry. At the beginning and after dryness is achieved, the weight of the substance is measured. The final weight loss is calculated, and represents the moisture content of the sample. A variety of techniques is used to bring about vaporization of moisture, including a drying oven heated by gas, which works on convection, and ovens which work by infrared or microwave radiation ^[41]. The loss on drying (LOD) for herbal powder used in facial packs generally falls within a range of 3% to 10% w/w. This parameter measures the moisture content and volatile matter, with lower values preferred to prevent microbial growth and enzymatic degradation, ensuring a stable, free-flowing product.

Weight of the empty petriplate(W_1)= 37.01

Weight of the petriplate + sample before drying(W_2)= 39.03

Weight of the petriplate+ sample after drying(W_3)= 38.94

Calculation:

$$\begin{aligned}\text{Loss on drying (\%w/w)} &= (W_2 - W_3) / (W_2 - W_1) \times 100 \\ &= 39.03 - 38.94 / 39.03 - 37.01 \times 100 \\ &= 0.09 / 2.02 \times 100 \\ &= 4.4\%\end{aligned}$$



Figure No.5: Loss On Drying

C. General Powder Properties: It includes tapped density, bulk density, angle of repose, hausner's ratio, Carr's index.

1. Tapped Density: Tapped density is an increased bulk density attained after mechanically tapping a container containing the powder sample. After observing the initial powder volume or mass, the measuring cylinder or vessel is mechanically tapped for 1 min and volume or mass readings are taken until little further volume or mass change was observed. It was expressed in grams per cubic centimetre (g/cm³)^[44].

Typically, fine-textured herbal face packs show tapped density values around **0.40–0.75 g/mL**, which indicates good compressibility and flowability.

Tapped density= Mass(50)/Tapped density

$$= 50/85=0.58\text{g/ml}$$



Figure No.6: Tapped Density

2. Bulk Density: Bulk Density is the ratio between the given mass of a powder and its bulk volume. Required amount of the powder is dried and filled in a 50 ml measuring cylinder up to 50 ml mark. Then the cylinder is dropped onto a hard wood surface from a height of 1 inch at 2 second intervals. The volume of the powder is measured. Then the powder is weighed. This is repeated to get average values. The Bulk Density is calculated by using the below given formula^[45]. The bulk density typically ranges from 0.28 g/mL to 0.66 g/mL

$$\text{Bulk Density} = \text{Mass}(50) / \text{Bulk volume}(\text{ml})$$

$$= 50/100$$

$$= 0.5\text{g/ml}$$

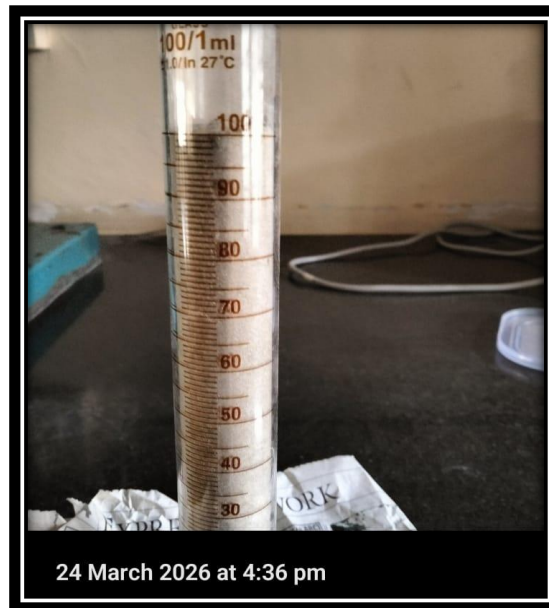


Figure No.7: Bulk Density

3. Angle of Repose: It is defined as the maximum angle possible in between the surface of pile of powder to the horizontal flow. It required amount of dried powder is placed in a cylindrical tube open at both ends is placed on a horizontal surface. Then the funnel should be raised to form a heap. The height and radius of the heap is noted and recorded. For the above method, the angle of repose (θ) Can be calculated by using the formula^[44].

$\theta = \tan^{-1} (h / r)$ Where,

θ – Angle of repose,

h – Height of the heap,

r – Radius of the base.

Trial 1: 35.82°

Trial 2: 31.79°

Trial 3: 34.21°

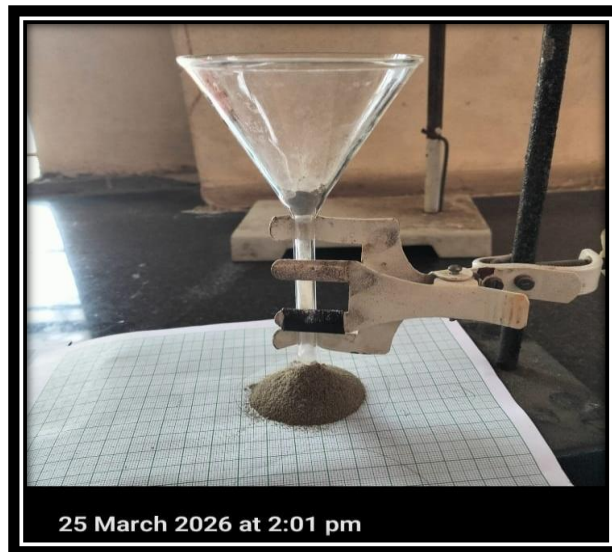


Figure No.8: Angle of Repose

4. Hausner's Ratio: It is expressed as the tap density divided by the bulk density.

The preferred range is **1.00–1.25**, with **1.12–1.18** indicating "good" to "fair" flow properties.

Hausner's Ratio= Tapped×bulk

$$= 0.58/0.5$$

$$= 1.16\%$$

5.Carr's Index: Carr's index is an indication of compressibility of powder. The preferred range is 10–25%, with 11–15% considered "good".

Carr's Index= $100 \times \frac{\text{Tapped}-\text{Bulk density}}{\text{Tapped}}$

$$=100 \times \frac{0.58-0.5}{0.58}$$

$$=13\%$$

6.Washability: This is the common method for checking the washability of the formulation. The formulation was applied on the skin and then ease and extent of washing with water were checked manually by using 1 liter of water is used to remove all content of the formulation were applied on the surface^[40].

D.Irritancy Test: Mark an area (1sq.cm) on the left-hand dorsal surface. Definite quantities of prepared face packs were applied to the specified area and time was noted. Irritancy, erythema, edema, was checked if any for regular intervals up to 24 hrs and reported^[44].



Figure No.9: Washability and Irritancy Test

RESULTS AND DISCUSSION

These formulations of herbal face pack containing variation in their composition were prepared, evaluated and studied its different properties and characteristics.

A.Organoleptic Properties: Appearance, colour, odour, texture, smoothness was observed as shown in table no. 2.

Table No 2: Organoleptic Properties of Herbal Face Pack

Sr. No.	Organoleptic Properties	Observation
1.	Nature	Powder
2.	Colour	Grey
3.	Odour	Slight
4.	Texture	Fine
5.	Smoothness	Smooth

B.Physicochemical Evaluation: Ash values, pH, LOD, acid insoluble ash, water soluble ash of all three batches of formulations were calculated and those calculations are as shown in Table 3.

Table No 3: Physicochemical Properties of Herbal Face Pack

Sr. No.	Physicochemical Properties	Observation
1.	Ash Value	0.35
2.	pH	6.0
3.	LOD	4.4%
4.	Acid insoluble	1.5%
5.	Water soluble Ash	3%

C. General Powder Characteristics: Various characteristics of formulations like angle of repose, bulk density, tapped density, Carr's index, hausner's ratio, wash ability, grittiness and nature of face after wash were performed and results are as shown in Table No.4 which are desirable as cosmetics face packs.

Table No 4: General Powder Characteristics of Herbal Face Pack

Sr. No.	General powder characteristics	Observation
1.	Angle of repose	Excellent
2.	Bulk density	0.5%
3.	Tapped density	0.58%
4.	Carr's index	13%
5.	Hausner's Ratio	1.16%
6.	Washability	Easily washable
7.	Irritant	No irritant
8.	Nature of face after wash	Soft and clean

D.Irritancy Test: The result of irritancy test was shown in Table no.5. The formulation showed absence of irritation, redness and swelling during irritancy studies. This formulation is safe to use on skin.

Table No 5: Irritancy test.

Sr. No.	Parameter	Observation
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1.	Irritation	No irritation
2.	Redness	No redness
3.	swelling	No swelling

CONCLUSION

Natural remedies are more acceptable in the belief that they are safer with fewer side effects than the synthetic ones. Herbal formulations have growing demand in the world market. Herbal face packs are used to stimulate blood circulation, rejuvenate the muscles and help to maintain the elasticity of the skin and remove dirt from skin pores. After formulation and evaluation, we found good properties for the face pack, free from skin irritation and maintained consistency after stability storage conditions. This herbal face pack having enough potential to give efficient clear, healthy and glowing effect on skin. Licorice has the ability to help you obtain a more even skin tone by lowering skin pigmentation. It is suggested that the prepared formulation was physicochemically and microbiologically stable, and possessed characteristics of a standard cosmeceutical's formulation for skin. Herbal face packs help to remove the spots, dirt, and skin debris and also cleanse and beautify the facial skin.

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