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Floral Waste Management Through Bio-Enzyme Production and Development of Eco- Friendly Herbal Insect Repellent Incense Sticks

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ABSTRACT

Floral waste generated from temples and flower markets forms a significant portion of biodegradable municipal solid waste and is often disposed of improperly, leading to environmental pollution and greenhouse gas emissions. This study focuses on the sustainable management and valorization of floral waste through the production of bio-enzymes and the development of eco-friendly herbal insect repellent incense sticks. Floral waste such as marigold, jasmine, rose, tuberose, and chrysanthemum was collected, segregated, and processed. Bio-enzyme was prepared using jaggery and sugar as fermentation substrates under anaerobic conditions for 90 days. The prepared bio-enzyme was analyzed for physico-chemical parameters such as pH, yield, and foam stability, along with practical cleaning efficiency tests. Results showed that the jaggery-based bio-enzyme exhibited better performance with higher acidity, improved foam stability, and enhanced cleaning properties. In parallel, dried floral waste was utilized to develop herbal insect repellent incense sticks using natural ingredients such as neem, tulsi, and lemongrass. The prepared sticks demonstrated longer burning duration, low ash residue, and high fragrance acceptability compared to commercial products. Theoretical validation indicated strong insect-repellent potential due to the presence of bioactive phytochemicals. The study highlights that floral waste can be effectively converted into eco-friendly, biodegradable, and value-added products. This approach supports waste-to-wealth conversion, reduces landfill burden, and promotes sustainable and decentralized waste management practices.

Keywords: *Floral waste, Bio-enzyme, Herbal insect repellent Incense sticks, Eco-friendly products.*

1. INTRODUCTION

Rapid urbanization and population growth have led to a significant increase in municipal solid waste generation. Among the various types of biodegradable waste, floral waste generated from temples, religious ceremonies, and flower markets constitutes a considerable portion [1][3]. In culturally rich regions like Mysuru, flowers are used extensively for daily rituals and decorative purposes. After use, these flowers are often discarded into open dumps, water bodies, or mixed with municipal waste, leading to environmental pollution, foul odor, and emission of greenhouse gases during decomposition [3][5]. Although floral waste is biodegradable, improper disposal can result in secondary environmental issues such as leachate formation, methane emissions, and blockage of drainage systems [3]. Therefore, there is a growing need for sustainable and decentralized waste management strategies that focus on resource recovery rather than disposal. Converting biodegradable waste into value-added products supports the concept of a circular economy, where waste materials are transformed into useful and environmentally friendly resources [1][3][5].

One effective approach for floral waste utilization is the production of bio-enzyme [8][9]. Bio-enzymes are naturally fermented liquids produced from organic waste materials in the presence of a carbohydrate source under anaerobic conditions [8]. These enzymes contain organic acids and bioactive compounds that exhibit cleaning, antimicrobial, and deodorizing properties. Being biodegradable and non-toxic, bio-enzymes serve as eco-friendly alternatives to chemical cleaning agents [8][9].

In addition to bio-enzyme production, floral waste can also be utilized for preparing eco-friendly herbal insect repellent incense sticks [1][2][6]. Conventional insect repellents often contain synthetic chemicals that may cause respiratory problems and environmental harm [7]. In contrast, plant-based ingredients such as neem, tulsi, and lemongrass possess natural insect-repellent properties due to their bioactive compounds [5][6]. Incorporating these materials into incense sticks provides a safer and sustainable alternative [5][7].

The present study focuses on the conversion of floral waste into two value-added products: bio-enzyme and herbal insect repellent incense sticks. This integrated approach not only addresses the issue of waste disposal but also promotes sustainable product development, reduces environmental pollution, and encourages eco-friendly practices at the household and community level [1][3][5].

2. REVIEW OF LITERATURE

Recent studies have increasingly focused on the sustainable utilization of floral waste, particularly from temples and religious activities, for the production of value-added products such as incense sticks and bioenzymes. R. Jadhav, S. Patil, and A. Deshmukh (2025) investigated the conversion of floral waste

into paper and natural incense sticks. Their methodology involved segregation, drying, grinding, and sieving of discarded flowers, followed by the preparation of incense sticks using natural binders. The products were evaluated for burning time, ash content, and moisture level, demonstrating efficient combustion, acceptable residue, and natural fragrance. The study emphasized the potential of floral waste valorization in reducing environmental pollution and promoting sustainable waste management.

Similarly, S. Kusumlata, R. Verma, and P. Singh (2025) examined different formulations of dhoopbatti prepared from temple flower waste combined with charcoal powder, jiggat powder, and herbal additives. Their findings indicated that optimized formulations significantly enhanced burning duration, structural stability, fragrance diffusion, and overall sensory properties, highlighting the importance of ingredient selection in improving product quality. Tiwari, S. Mishra, and V. Gupta (2025) focused on the sustainable production of incense sticks from temple floral waste without synthetic additives. Their study evaluated parameters such as moisture content, combustion efficiency, and fragrance retention, while also emphasizing socio-economic benefits, including employment generation for local communities and self-help groups. The authors concluded that such practices contribute to both environmental sustainability and rural economic development. K. Ananda and M. Dasalukunte (2023) explored the physicochemical characteristics of floral waste using advanced analytical techniques such as scanning electron microscopy (SEM) and energy dispersive X-ray spectroscopy (EDS). Their results revealed variations in carbon composition among different flower types, indicating differential suitability for incense stick production and underscoring the importance of scientific characterization in product optimization. Kalyankar (2024) investigated the environmental and socio-economic aspects of eco-friendly incense stick production from floral waste. The study reported that incense sticks produced without synthetic additives emitted fewer harmful pollutants and contributed to improved indoor air quality. Additionally, it highlighted the role of such initiatives in employment generation and sustainable waste management practices. S.K. Sagar, M. Reddy, and V. Kumar (2023) focused on optimizing incense stick formulations using marigold flower waste. Their evaluation of burning duration, ash content, and fragrance retention indicated that balanced formulations significantly improved combustion efficiency and overall product performance. A. Saini, D. Rawat, and K. Joshi (2024) assessed indoor air quality impacts of incense sticks derived from floral waste. Their findings demonstrated reduced smoke emission and lower levels of harmful pollutants compared to conventional incense sticks, suggesting that eco-friendly alternatives are safer for indoor environments. In addition to incense production, research has also explored the use of floral waste for bioenzyme generation. R. Shrivastava, A. Dubey, and M. Saxena (2022) highlighted the antimicrobial properties, biodegradability, and cleaning efficiency of bioenzymes derived from organic waste, establishing them as eco-friendly alternatives to chemical cleaning agents. Further, A. Kumar, S. Bakshi, and R. Tyagi (2023) evaluated the application of bioenzymes derived from flower waste in greywater treatment. Their results demonstrated significant pollutant reduction and improved water quality, indicating the potential of such bioenzymes in environmental remediation.

Overall, the reviewed literature clearly indicates that floral waste can be effectively utilized for producing eco-friendly incense products and bioenzymes, contributing to waste reduction, environmental protection, and socio-economic development.

3. MATERIALS AND METHODOLOGY

3.1 Preparation of Bio-Enzyme from Floral Waste

3.1.1 Materials Required

- Mixed floral waste (marigold, jasmine, rose, tuberose, chrysanthemum)
- Jaggery (for Batch 1)
- Sugar (for Batch 2)
- Filtered, boiled, and cooled water
- Airtight plastic containers
- Digital weighing machine
- Knife and clean trays for cutting and drying

3.1.2 Collection and Pre-processing of Floral Waste

Floral waste was collected from nearby temples and local flower markets. The collected material was manually segregated to remove non-biodegradable impurities such as plastic, threads, and wires. Only fresh and clean petals were retained. The petals were washed thoroughly to remove dust and impurities and then sun-dried for several hours to reduce moisture content and prevent microbial contamination.

Fig 1: Collection, Segregation and Sun Drying

3.1.3 Preparation of Bio-Enzyme

Bio-enzyme was prepared using the standard ratio of 3:1:10 (floral waste : carbohydrate source : water).

- **Batch 1 (Jaggery-based):**
  - 800 g floral waste
  - 270 g jaggery
  - 2.7 L water

- **Batch 2 (Sugar-based):**
  - 300 g floral waste
  - 100 g sugar
  - 1 L water

All ingredients were mixed thoroughly in airtight plastic containers. About 30% empty space was left for gas formation during fermentation. The containers were sealed and kept under anaerobic conditions for 90 days.

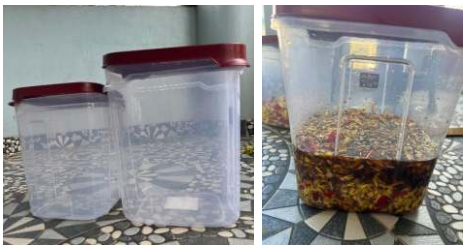

Fig 2: Airtight container used for bio Enzyme Fermentation

3.1.4 Fermentation and Harvesting

After 90 days, the fermented mixture was opened. A white yeast layer indicated successful fermentation. The liquid bio-enzyme was separated using a two-step filtration process (cloth filtration followed by fine filtration) and stored in clean containers for further analysis and application.

Fig 3: Harvesting process: Yeast Layer Observation and Double Filtration

3.2 Preparation of Eco-Friendly Instant Insect Repellent Sticks

3.2.1 Materials Required

- Dried floral waste powder
- Wood sawdust powder
- Neem powder
- Tulsi powder
- Lemongrass powder
- Guar gum powder (binding agent)
- Water and rose water
- Bamboo sticks

3.2.2 Preparation of Raw Materials

The collected floral waste was thoroughly dried under sunlight and then ground into fine powder. All other ingredients such as neem, tulsi, and lemongrass powders were measured in required proportions.

3.2.3 Preparation of Dry Mixture

All dry ingredients (floral powder, sawdust, neem, tulsi, lemongrass, and guar gum) were mixed uniformly on a clean surface to obtain a homogeneous mixture.

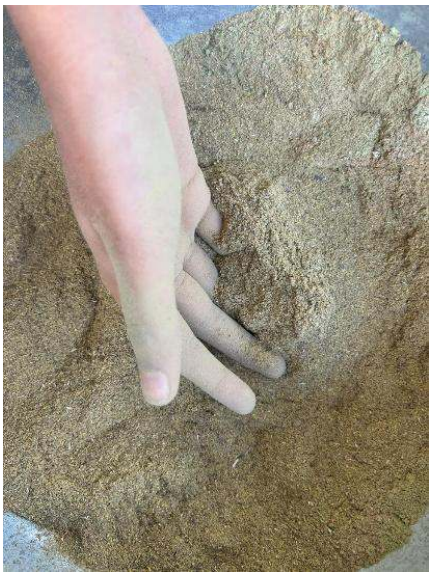

Fig 4: Preparation of Dry Powder Mixture

3.2.4 Dough Formation

Water and rose water were gradually added to the dry mixture. The mixture was kneaded properly to form a smooth and pliable dough. Guar gum acted as a natural binder to improve cohesion and strength [2][6].

Fig 5: Addition of liquid binding agents and dough formation

3.2.5 Rolling and Shaping

Small portions of dough were taken and uniformly coated onto bamboo sticks by hand rolling. Care was taken to maintain uniform thickness for consistent burning.

3.2.6 Drying of Incense Sticks

The prepared sticks were dried in the shade at room temperature until they became firm. Shade drying was preferred to preserve aroma and prevent cracking.

4. RESULTS

4.1 Results of Bio-Enzyme

The bio-enzyme prepared from floral waste using jaggery and sugar as fermentation substrates showed successful fermentation after 90 days. The results were analyzed based on physical, chemical, and functional parameters.

4.1.1 Physical and Organoleptic Characteristics

The harvested bio-enzymes were observed visually and through sensory evaluation.

- **Jaggery-based bio-enzyme (Batch 1):**
  - Color: Dark brown
  - Odor: Strong vinegar-like smell
  - Appearance: Clear liquid with slight sediment

- **Sugar-based bio-enzyme (Batch 2):**
  - Color: Light yellow
  - Odor: Mild acidic smell
  - Appearance: Clear liquid

- A thin white layer (yeast) was observed in both samples, indicating healthy microbial activity.
- No green or black fungal growth was observed, confirming absence of contamination

Inference:
The darker color and stronger odor in the jaggery-based sample indicate a higher degree of fermentation due to the presence of minerals and nutrients in jaggery.

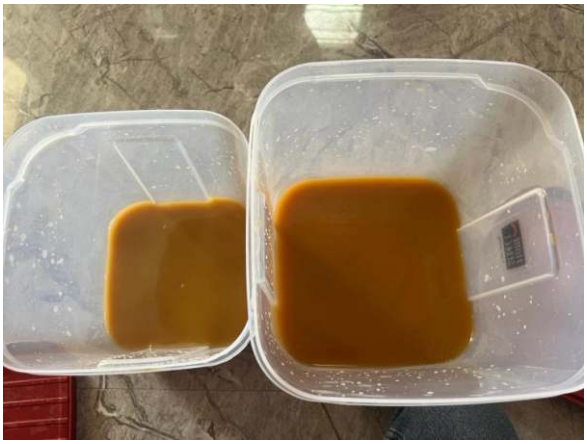

Fig 6: Comparative color profile analysis

4.1.2 pH Analysis
The pH of both bio-enzyme samples was measured using pH indicator strips.
- Jaggery-based bio-enzyme: pH 3.5
- Sugar-based bio-enzyme: pH 3.8

Inference:
Both samples fall within the ideal acidic range (pH 3–4), confirming successful fermentation and production of organic acids such as acetic acid and lactic acid. The lower pH in the jaggery-based sample indicates stronger fermentation.

4.1.3 Foam Stability Test
The foam stability test was conducted to evaluate the cleaning potential of the bio-enzyme.
- Jaggery-based: 20 seconds
- Sugar-based: 15 seconds

Inference:
Higher foam stability indicates the presence of active enzymes and natural surfactants. The jaggery-based bio-enzyme showed better cleaning efficiency.

4.1.4 Sedimentation Test
The samples were kept undisturbed for 24 hours to observe sediment formation.
- Both samples showed **slight sediment at the bottom**

Inference:
The presence of slight sediment is normal and indicates proper breakdown of organic matter. It also confirms effective filtration.

4.1.5 Yield Analysis
The yield of bio-enzyme was calculated based on volume recovery.

- Jaggery-based: 103.7%
- Sugar-based: 100%

Inference:
The higher yield in the jaggery-based sample is due to release of intracellular moisture from floral waste and the formation of fermentation metabolites.

4.1.6 Application Performance (Dissolution and Cleaning Efficiency)
The prepared bio-enzyme was tested in real-life applications to evaluate its performance.

a) Descaling of Metal Surfaces
- Removed hard water stains from taps
- Restored shine and smooth surface

Reason: Acidic nature dissolves mineral deposits.

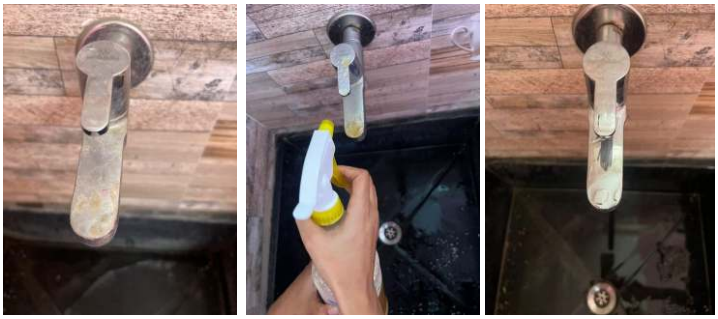

Fig 7: Comparative analysis of tap surface before and after cleaning using floral bio enzyme

b) Floor Cleaning
- Effectively removed dirt, mud, and stains
- Improved surface cleanliness

Reason: Enzymes break down organic matter.

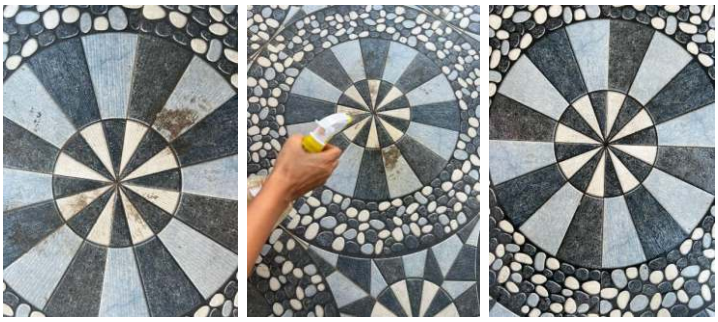

Fig 8: Cleaning of floor surface using floral bio enzyme

c) Glass and Mirror Cleaning
- Removed fingerprints and oil smudges
- Provided clear and streak-free finish

Reason: Bioactive compounds act as natural cleaners.

d) Degreasing of Utensils
- Reduced grease and oil residues
- Left no chemical residue

Reason: Enzymes like lipase break down fats.

e) Plant Application (Insect Repellent Activity)
- No damage to plants observed
- Insects moved away after spraying

Reason: Organic acids and plant compounds act as natural repellents.

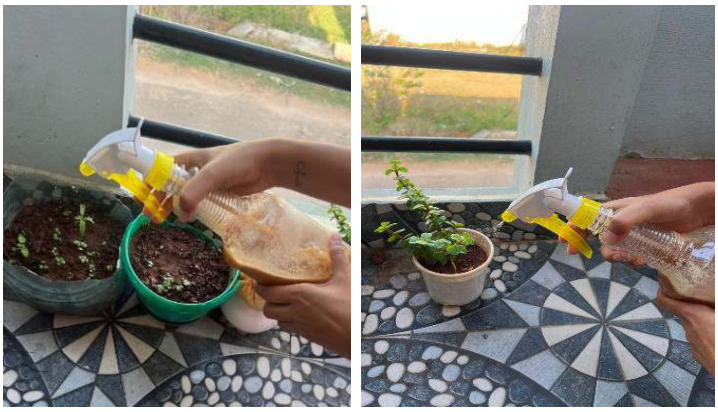

Fig 9: Spraying of floral bio enzyme solution on plants

4.1.7 Overall Performance of Bio-Enzyme

The bio-enzyme demonstrated:

- Strong cleaning efficiency
- Effective descaling and degreasing properties
- Eco-friendly and biodegradable nature
- Potential insect-repellent activity

The jaggery-based bio-enzyme performed better compared to the sugar-based formulation.

4.2 Results of Instant Insect Repellent Sticks

The prepared herbal incense sticks were evaluated based on physical, combustion, and sensory properties.

Fig 9: Spraying of floral bio enzyme solution on plants

4.2.1 Weight Analysis

- Prepared sticks: 3.03 ± 0.06 g
- Commercial stick: 1.27 g

Inference:
Higher weight indicates better material composition and uniformity.

4.2.2 Burning Time Test

- Prepared sticks: 58.14 ± 4.47 minutes
- Commercial stick: 43.20 minutes

Inference:
Prepared sticks showed longer burning duration, ensuring prolonged effect.

4.2.3 Ash Residue Analysis

- Prepared sticks: **7.71% ash**
- Commercial stick: **78.74% ash**

Inference:
Lower ash indicates cleaner combustion and eco-friendly nature.

4.2.4 Moisture Content Loss

- Range: **40% – 50%**
- Mean: **43.33 ± 5.77%**

Inference:
Proper drying ensures stability, strength, and better burning quality.

4.2.5 Sensory Evaluation

- Smoke intensity: Low to moderate (2.33/5)
- Fragrance acceptability: High (4.33/5)

Inference:
Pleasant fragrance and low smoke make it suitable for indoor use.

4.2.6 Overall Performance of Incense Sticks

The prepared sticks showed:

- Longer burning duration
- Low ash formation
- Pleasant fragrance
- Eco-friendly composition

They performed **better than commercial incense sticks**.

5. DISCUSSION

The present study focused on the sustainable utilization of floral waste through the production of bio-enzymes and eco-friendly herbal insect repellent incense sticks. The results obtained clearly demonstrate that floral waste, which is often discarded and contributes to environmental pollution, can be effectively converted into valuable and functional products. This supports the "waste-to-wealth" paradigm [1]. Furthermore, similar studies [3] emphasize the environmental and socio-economic benefits of converting temple waste into value-added products, reinforcing the significance of the present work.

5.1 Bio-Enzyme Production

The bio-enzyme prepared using floral waste showed successful fermentation in both jaggery-based and sugar-based batches. The acidic pH values (3.5–3.8) confirm the formation of organic acids such as acetic and lactic acid, which are responsible for the antimicrobial and cleaning properties observed. These findings are consistent [8], who established that the acidic nature of bio-enzymes makes them potent natural alternatives to chemical agents due to their enzymatic activity.

A comparative analysis revealed that the jaggery-based formulation exhibited superior performance, including a stronger acidic odor and higher foam stability. The minerals and complex nutrients present in jaggery likely supported a richer microbial community, leading to enhanced enzyme production. These observations are in agreement with [9], who reported that bio-enzymes derived from organic waste exhibit strong efficiency in environmental applications, particularly in degradation and cleaning processes.

The practical usability of the enzyme as a descaler and degreaser, combined with its safety as a foliar spray, establishes it as a versatile, eco-friendly alternative to conventional chemicals.

5.2 Herbal Insect Repellent Incense Sticks

The preparation of incense sticks yielded promising results, with the physical parameters indicating a stable and consistent formulation. The burning time analysis showed that the prepared sticks had a significantly longer duration compared to commercial alternatives. This sustained combustion can be attributed to the balanced composition of floral biomass and natural binders, which aligns with optimized formulations [6].

The ash residue analysis revealed a significantly lower percentage (7.71%) compared to commercial products, indicating efficient combustion and minimal use of synthetic fillers. This environmental advantage contributes to improved indoor air quality, as emphasized [7]. Furthermore, the incorporation of plant-based ingredients such as neem, tulsi, and lemongrass provides a strong theoretical basis for insect repellency due to bioactive compounds like azadirachtin and citral. As noted [5], the use of natural ingredients not only enhances functionality but also contributes to economically viable waste management solutions.

By replacing charcoal-based sticks with these floral-waste alternatives, the study addresses respiratory discomfort and pollution, aligning with sustainability goals [4][2].

6. CONCLUSION

The present study successfully demonstrates a sustainable and eco-friendly approach for the management and utilization of floral waste through its conversion into value-added products, namely bio-enzyme and herbal insect repellent incense sticks. Floral waste, which is generated in large quantities from temples, religious activities, and flower markets, often contributes to environmental pollution when disposed of improperly. This research highlights an effective method to transform such biodegradable waste into useful products, thereby reducing environmental burden and promoting resource recovery. The preparation of bio-enzyme from floral waste was carried out using a controlled anaerobic fermentation process following the standard ratio of 3:1:10 (organic waste : carbohydrate source : water). Both jaggery-based and sugar-based formulations showed successful fermentation, as indicated by acidic pH, absence of fungal contamination, and characteristic odor. However, the jaggery-based bio-enzyme exhibited superior performance in terms of lower pH, higher foam stability, stronger odor, and slightly higher yield. This confirms that jaggery, due to its rich nutrient content, enhances microbial activity and improves the quality of the final product.

The application studies further validated the effectiveness of the bio-enzyme as a multi-purpose cleaning agent. It demonstrated excellent performance in removing stains, grease, and mineral deposits from various surfaces such as taps, floors, glass, and utensils. Additionally, its use as a foliar spray showed insect-repellent activity without causing harm to plants, indicating its potential application in organic gardening and sustainable household practices. These findings establish bio-enzyme as a safe, biodegradable, and eco-friendly alternative to chemical-based cleaning products.

The second part of the study focused on the preparation of eco-friendly herbal insect repellent incense sticks using floral waste and natural plant-based ingredients. The prepared sticks showed desirable physical and functional properties, including uniform weight, longer burning duration, low ash residue, and high fragrance acceptability. Compared to commercial incense sticks, the developed formulation proved to be more efficient, clean-burning, and environmentally friendly. The low smoke emission and pleasant aroma further enhance its suitability for indoor use. Although direct experimental validation of insect repellent activity was not conducted, the theoretical basis supported by phytochemical properties of neem, tulsi, and lemongrass indicates strong repellent potential. The presence of bioactive compounds such as azadirachtin and citral contributes to the effectiveness of the formulation in repelling insects through natural mechanisms.

Overall, the study clearly establishes that floral waste can be effectively utilized as a raw material for the production of sustainable, biodegradable, and high-performance products. The approach supports the concept of waste-to-wealth and aligns with circular economy principles by converting waste into valuable resources. Moreover, the methods used are simple, cost-effective, and suitable for small-scale as well as community-level implementation. In conclusion, this research provides a practical solution for floral waste management while promoting eco-friendly alternatives to synthetic products. It contributes to environmental protection, pollution reduction, and sustainable development. Future research can focus on large-scale production, microbial analysis, shelf-life studies, and direct biological testing of insect repellent efficiency to further enhance the scientific validation and commercial potential of these products.

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