IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 11, May 2026
Impact Factor: 8.2

Formulation and Evaluation of An Eco-Friendly Herbal Mosquito Repellent Fumigant

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Abstract: *Mosquito-borne diseases continue to represent a major public health challenge worldwide, particularly in tropical and developing regions where environmental conditions favor rapid mosquito breeding and transmission of infectious diseases such as malaria, dengue, chikungunya, and filariasis. Although synthetic mosquito repellents and coils are widely used for vector control, their prolonged usage has been associated with adverse health effects, environmental pollution, and respiratory discomfort due to the release of toxic chemicals and non-biodegradable residues. These limitations have created a growing demand for safer, sustainable, and eco-friendly alternatives derived from natural sources.*

The present study focuses on the formulation and evaluation of an eco-friendly herbal mosquito repellent fumigant prepared using naturally available plant-based materials. The formulation was developed using neem powder as the primary herbal repellent agent, along with eucalyptus oil for enhanced mosquito repellent activity and aromatic effect. Activated charcoal and sawdust were incorporated to improve combustion characteristics and maintain uniform burning, while starch-based binder was utilized for proper consistency and structural integrity of the fumigant. The prepared formulation was molded into fumigant cones and dried under controlled conditions to obtain suitable hardness and stability.

The formulated herbal fumigant was evaluated for various physicochemical and performance parameters including burning time, smoke generation, ash content, odor acceptability, physical appearance, and mosquito repellent efficacy. The developed formulation demonstrated satisfactory burning behavior, sustained smoke release, acceptable stability, and effective mosquito repellent activity without the use of harmful synthetic chemicals. Furthermore, the utilization of biodegradable and low-cost ingredients makes the formulation economical, environmentally sustainable, and suitable for domestic application.

The study concludes that the formulated eco-friendly herbal mosquito repellent fumigant may serve as a promising natural alternative to conventional synthetic mosquito repellents, with potential benefits in public health protection and environmental safety.

Keywords: Herbal mosquito repellent, Eco-friendly fumigant, Neem powder, Eucalyptus oil, Vector control, Biodegradable formulation, Mosquito repellency, Herbal formulation

I. INTRODUCTION

Mosquito-borne diseases remain one of the most significant public health concerns affecting millions of people worldwide. Mosquitoes act as vectors for several life-threatening infectious diseases including malaria, dengue fever, chikungunya, yellow fever, Japanese encephalitis, and lymphatic filariasis. These diseases continue to place a major burden on healthcare systems, particularly in tropical and subtropical countries where climatic conditions support rapid mosquito breeding and transmission. According to global health reports, the incidence of mosquito-associated illnesses has increased considerably due to urbanization, population growth, poor sanitation, climate change, and stagnant water accumulation.[1] Among these diseases, malaria and dengue are responsible for substantial morbidity and mortality, especially among children and economically vulnerable populations.[2]

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The rapid increase in mosquito populations has become a major challenge in both urban and rural communities. In many developing countries, inadequate waste management systems, water storage practices, and environmental pollution create ideal breeding habitats for mosquitoes.[3] Furthermore, global warming and changing rainfall patterns have contributed to the expansion of mosquito habitats into previously unaffected geographical regions.[4] As a result, mosquito control has become an essential component of disease prevention and public health protection.

Various synthetic mosquito repellents, insecticidal sprays, vaporizers, coils, creams, and mats are commercially available and widely used for mosquito control. Most conventional mosquito repellents contain synthetic chemicals such as allethrin, pyrethroids, N,N-diethyl-meta-toluamide (DEET), and other volatile compounds that provide effective repellent activity.[5] Although these products offer temporary protection against mosquito bites, their prolonged and excessive use has raised concerns regarding human health and environmental safety.

Studies have reported that continuous exposure to smoke generated from synthetic mosquito coils may cause respiratory irritation, allergic reactions, eye irritation, headaches, coughing, and other pulmonary complications.[6] The smoke emitted from synthetic repellents may contain harmful particulate matter, volatile organic compounds, and toxic residues that can negatively affect indoor air quality.[7] In addition, the non-biodegradable nature of many chemical repellents contributes to environmental pollution and ecological imbalance.[8] Growing awareness regarding these adverse effects has encouraged researchers to explore safer and more sustainable alternatives derived from natural resources.

Herbal and plant-based mosquito repellents have gained increasing scientific and commercial attention due to their eco-friendly nature, biodegradability, lower toxicity, and traditional acceptance.[9] Since ancient times, medicinal plants and aromatic herbs have been used in various cultures to repel insects and protect against mosquito bites. Plant-derived essential oils and herbal extracts possess bioactive compounds such as terpenoids, flavonoids, alkaloids, tannins, and phenolic constituents that exhibit mosquito repellent, larvicidal, and insecticidal activities.[10]

Among various medicinal plants, neem (Azadirachta indica) has been widely recognized for its significant mosquito repellent and insecticidal properties. Neem contains biologically active constituents such as azadirachtin, nimbin, and salannin, which interfere with mosquito feeding and survival.[11] Several studies have demonstrated that neem-based formulations provide effective protection against mosquito species responsible for malaria and dengue transmission.[12] Neem is also biodegradable, economical, and easily available in many parts of India, making it highly suitable for herbal mosquito repellent formulations.

Eucalyptus oil is another important natural ingredient commonly used in herbal mosquito repellents. The essential oil obtained from Eucalyptus species contains compounds such as eucalyptol and citronellal that possess strong aromatic and repellent properties.[13] Eucalyptus oil has been investigated extensively for its effectiveness against different mosquito vectors and is considered one of the most promising natural alternatives to synthetic repellents.[14] Apart from repellent action, eucalyptus oil also imparts a pleasant aroma and contributes to the overall acceptability of herbal formulations.

The increasing demand for herbal mosquito control products has led to the development of various dosage forms including sprays, creams, lotions, candles, coils, patches, vaporizers, incense sticks, and fumigants.[15] Among these, herbal fumigants and dhoup-based preparations are gaining popularity because they are simple to prepare, economical, and suitable for household use. Traditionally, dhoup or fumigation practices have been used in Indian households for purification of air and control of insects using natural smoke generated from herbal materials.[16] Herbal fumigants work by releasing aromatic smoke containing volatile phytoconstituents that create an unfavorable environment for mosquitoes.

The concept of herbal fumigation combines traditional knowledge with modern scientific approaches for vector control. Compared to synthetic coils, herbal fumigants are considered safer because they are prepared from biodegradable plant materials and generally contain fewer toxic additives.[17] Additionally, herbal fumigants can be prepared using locally available ingredients such as neem leaves, plant powders, sawdust, charcoal, essential oils, and

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natural binders. Their low production cost and easy preparation method make them suitable for large-scale domestic application, especially in resource-limited communities.

Activated charcoal is commonly incorporated in herbal fumigant formulations to improve combustion characteristics and maintain uniform burning. Sawdust or coconut shell powder is often used as a supporting combustible material to prolong burning time and facilitate smoke generation.[18] Natural binders such as starch or gum-based materials help in maintaining structural integrity and proper consistency of the fumigant cones or sticks. The incorporation of herbal essential oils enhances both repellent efficacy and fragrance of the final formulation.

In recent years, researchers have focused extensively on the development of eco-friendly mosquito repellent products due to growing concerns regarding chemical toxicity and environmental sustainability.[19] Eco-friendly herbal formulations are considered advantageous because they minimize exposure to harmful synthetic compounds while promoting the use of renewable plant-based resources. Furthermore, herbal products are generally perceived by consumers as safer, culturally acceptable, and environmentally responsible alternatives.

Despite the availability of several mosquito repellent products in the market, there remains a continuous need for affordable, effective, and sustainable herbal formulations suitable for domestic use. Many commercially available herbal products are expensive or contain synthetic additives that reduce their natural value. Therefore, the development of a simple and economical herbal mosquito repellent fumigant using easily available natural ingredients may provide a valuable alternative for mosquito control.

The present study focuses on the formulation and evaluation of an eco-friendly herbal mosquito repellent fumigant prepared using neem powder, eucalyptus oil, activated charcoal, sawdust, and natural binding agents. The formulation is designed to provide effective mosquito repellent activity while minimizing harmful environmental and health effects associated with synthetic repellents. The prepared herbal fumigant is further evaluated for important physicochemical and performance parameters including burning time, smoke generation, ash content, odor acceptability, physical appearance, stability, and mosquito repellent efficacy.

II. LITERATURE REVIEW

Mosquito-borne diseases remain a serious global health concern, especially in tropical and subtropical regions. Increasing resistance of mosquitoes to synthetic insecticides and growing environmental concerns have encouraged researchers to explore safer and more sustainable alternatives for mosquito control. Herbal mosquito repellents and plant-based fumigation systems have gained significant attention in recent years due to their eco-friendly nature and lower toxicity.

Herbal Mosquito Repellent Research

Several n have reported the effectiveness of plant-based mosquito repellents derived from essential oils and crude plant extracts. Herbal repellents are considered safer alternatives to synthetic chemicals such as DEET and pyrethroids. Research indicates that plant-derived compounds like terpenoids, flavonoids, and phenolic substances interfere with mosquito olfactory receptors, thereby reducing their ability to detect human hosts. Essential oils obtained from plants such as citronella, lemongrass, basil, clove, and eucalyptus have shown significant mosquito repellent activity under laboratory and field conditions [16,17].

Studies have also demonstrated that herbal formulations in the form of sprays, creams, and incense sticks provide moderate to strong protection against mosquito bites. These formulations are biodegradable, environmentally safe, and suitable for household applications. However, limitations such as shorter duration of action and variability in plant extract composition have also been reported in some studies [18,19].

Neem (Azadirachta indica) Studies

Neem has been extensively studied for its insecticidal and mosquito repellent properties.

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Research shows that neem contains biologically active compounds such as azadirachtin, nimbin, salannin, and gedunin, which play a major role in disrupting mosquito growth and reproduction. These compounds act as antifeedants, growth regulators, and oviposition deterrents against mosquito species [20,21]. Several studies have confirmed that neem oil and neem leaf extracts exhibit strong larvicidal and adult mosquito repellent activity. Neem-based formulations have been shown to reduce mosquito density and prevent mosquito breeding in treated areas. In addition, neem is widely available, cost-effective, and safe for human use, making it a highly suitable candidate for herbal mosquito control formulations [22,23].

Research also highlights that neem-based fumigation systems and smoke-based preparations can effectively repel mosquitoes when used in appropriate concentrations. However, some studies suggest that the effectiveness of neem products may vary depending on extraction method, concentration, and formulation type [24].

Eucalyptus and Other Herbal Oils

Eucalyptus oil has been widely investigated for its mosquito repellent activity. The oil contains compounds such as eucalyptol (1,8-cineole) and citronellal, which are responsible for its strong insect-repelling properties. Studies show that eucalyptus oil provides significant protection against mosquito bites and is often used in combination with other essential oils to enhance efficacy [25,26]. Its pleasant aroma and natural origin make it suitable for fumigation-based formulations.

Other plant-based oils such as citronella, peppermint, and lavender have also demonstrated mosquito repellent properties. These oils are commonly incorporated into herbal coils, sprays, and incense products to improve repellency and fragrance [27].

Fumigation and Dhoup-Based Studies

Fumigation-based mosquito control methods, including incense sticks, coils, and traditional dhoup, have been widely studied for their effectiveness. These systems work by releasing smoke containing volatile plant compounds that create an unfavorable environment for mosquitoes, thereby preventing human biting activity [28].

Research shows that herbal fumigants prepared using plant powders, essential oils, sawdust, and natural binders provide effective mosquito repellency with relatively lower toxicity compared to synthetic mosquito coils. Smoke from herbal fumigants disperses active volatile compounds into the environment, ensuring prolonged mosquito protection in indoor spaces [29].

Activated charcoal and sawdust are commonly used in fumigant formulations to support combustion and maintain steady burning. Studies suggest that these materials improve smoke generation and burning duration, which are essential for effective mosquito repellent action [30]. Natural binders such as starch, gum tragacanth, and plant resins are used to provide structural integrity to fumigant cones and sticks [31].

Evaluation and Formulation Studies

Several studies have focused on the development and evaluation of herbal mosquito repellent formulations. Parameters such as burning time, smoke density, stability, repellency percentage, and ash content are commonly assessed to determine product efficiency. Research indicates that optimized formulations with balanced proportions of herbal powder, combustible base, and binders provide better performance and user acceptability [32,33].

Formulation studies also highlight the importance of maintaining consistency in raw materials and proper drying techniques to ensure product stability and uniform combustion. Herbal fumigants are considered promising alternatives to synthetic mosquito coils due to their ecofriendly nature and reduced health risks [34].

Research Gap

Although many herbal mosquito repellent formulations have been developed, most available products lack standardization, consistent efficacy, and cost-effectiveness. There is still a need for simple, affordable, and

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scientifically validated herbal fumigant formulations that can be easily prepared using locally available ingredients. This creates scope for developing improved ecofriendly mosquito repellent fumigants using neem, eucalyptus, and other plant-based materials [35].

III. AIM AND OBJECTIVES

Aim

The aim of the present study is to develop a simple, cost-effective, eco-friendly, and scientifically effective herbal mosquito repellent fumigant using natural plant-based ingredients such as neem and eucalyptus, designed to provide safe and sustainable protection against mosquitoes while minimizing the harmful effects associated with synthetic mosquito control products.

Objectives

1)To design and formulate an eco-friendly herbal mosquito repellent fumigant using easily available and biodegradable plant-based materials.
2)To utilize the mosquito-repellent potential of medicinal plants such as Azadirachta indica (Neem) and Eucalyptus oil in a stable dosage form.
3)To develop a fumigant (dhoup/cone) system that ensures controlled and uniform burning with continuous release of mosquito-repelling smoke.
4)To incorporate suitable natural excipients such as sawdust, coconut shell powder, and activated charcoal to enhance combustion properties and smoke generation.
5)To use a natural binder (such as starch or gum-based material) to achieve proper consistency, structural strength, and shape retention of the formulation.
6)To evaluate the prepared formulation for important physicochemical and performance parameters such as:
*Burning time
*Smoke density and consistency
*Ash content
*Physical appearance and stability
*Odor acceptability
*Mosquito repellency efficiency
7)To assess the safety, environmental compatibility, and biodegradability of the formulated product.
8)To promote an affordable and eco-friendly alternative to synthetic mosquito repellents for better public health protection and environmental sustainability.

Materials and Method of preparation

***Materials-**

Neem Powder
Family- Meliaceae

Neem (Azadirachta indica) is a well-known medicinal plant widely used in traditional and modern herbal formulations due to its strong insecticidal and mosquito repellent properties. In the present study, neem powder is selected as the primary herbal active ingredient for the formulation of the eco-friendly mosquito repellent fumigant. Neem contains biologically active compounds such as azadirachtin, nimbin, and salannin, which are responsible for its repellent, antifeedant, and growth-regulating effects against mosquitoes. These phytoconstituents interfere with mosquito feeding behavior and reproduction, thereby reducing mosquito population and human biting activity. Neem is also biodegradable, non-toxic at recommended levels, and easily available, making it highly suitable for sustainable herbal formulations. In fumigation systems, neem powder releases volatile compounds upon burning that contribute to

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mosquito repellent smoke, enhancing overall efficacy of the product and providing a safe alternative to synthetic mosquito repellents [36,37].

Fig,No.01 Neem Powder

2) Coconut Shell Powder

Family - Arecaceae (palm) family

Coconut shell powder is a natural lignocellulosic biomass derived from the hard shell of coconut fruit and is widely utilized in herbal fumigant and incense-based formulations due to its excellent combustion characteristics. In the present study, coconut shell powder is incorporated as a key base material in the formulation of the eco-friendly mosquito repellent fumigant. It provides structural strength to the cone and ensures uniform, slow, and sustained burning, which is essential for continuous release of mosquito-repellent smoke. Its high carbon content enhances ignition and combustion efficiency, thereby improving smoke density and stability during fumigation. The porous nature of coconut shell powder also facilitates gradual volatilization of active herbal constituents such as neem and eucalyptus, enhancing overall repellent effectiveness. Being biodegradable, lowcost, and readily available, it represents an environmentally sustainable excipient for herbal formulations. Additionally, it minimizes toxic residue formation, making the product safer for domestic use [38,39].

Fig No.02 Coconut Shell Powder

3) Eucalyptus Oil

Family – Myrtaceae

Eucalyptus oil is a volatile essential oil obtained from the leaves of Eucalyptus species and is widely recognized for its strong mosquito repellent and antimicrobial properties. In the present study, eucalyptus oil is incorporated as a key active herbal component in the formulation of an eco-friendly mosquito repellent fumigant. The oil contains bioactive constituents such as eucalyptol (1,8-cineole) and citronellal, which are responsible for its characteristic aroma and insect-repelling activity. These volatile compounds act on the olfactory receptors of mosquitoes, disrupting their host-seeking behavior and thereby reducing human–mosquito contact. During fumigation, eucalyptus oil vapors are released along with smoke, enhancing the overall repellent efficiency and providing a pleasant aromatic environment. In

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addition to its repellent action, eucalyptus oil also exhibits mild antimicrobial properties, contributing to improved air quality. Its natural origin, biodegradability, and compatibility with other herbal ingredients make it highly suitable for sustainable fumigant formulations [40,41].

Fig,No.03 Eucalyptus Oil

4) Activated charcoal

Activated charcoal is a highly porous form of carbon obtained from carbonaceous materials and is widely used in fumigant and incense-based formulations due to its excellent adsorption and combustion-supporting properties. In the present study, activated charcoal is incorporated as a functional excipient in the eco-friendly herbal mosquito repellent fumigant to enhance burning efficiency and smoke quality. Its large surface area and porous structure help in maintaining a steady and controlled combustion process, ensuring uniform release of herbal volatile compounds from neem and eucalyptus oil. Activated charcoal also improves ignition characteristics and stabilizes smoke production, which is essential for sustained mosquito repellent action. Additionally, it aids in adsorbing unwanted odorous gases produced during burning, thereby improving user acceptability. Being chemically stable, non-toxic in formulated use, and environmentally safe, activated charcoal contributes significantly to the performance and quality of herbal fumigant systems designed for mosquito control [42,43].

Fig, No.04 Activated charcoal

5) Starch –

Starch is a naturally occurring polysaccharide widely used in pharmaceutical and herbal formulations as a binding agent. In the preparation of eco-friendly herbal mosquito repellent fumigant, starch plays an important role in providing proper consistency, cohesiveness, and structural stability to the formulation. It helps in binding powdered ingredients such as coconut shell powder, neem powder, and activated charcoal into a uniform semi-solid mass, which can be molded into cone or stick form easily. Starch also contributes to controlled burning characteristics by maintaining the integrity of the fumigant during combustion. Due to its biodegradable, non-toxic, and eco-friendly nature, starch is considered suitable for herbal formulations intended for safer domestic use. Additionally, it improves handling properties and minimizes cracking during drying and storage. The use of starch in herbal fumigants supports the development of sustainable and environmentally friendly mosquito repellent products with improved physical properties and user acceptability. [44,45]

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*Method of preparation

Step 1: Drying and Sieving of Ingredients

All powdered materials including coconut shell powder, activated charcoal, neem powder, and starch were dried properly to remove excess moisture and then passed through a fine sieve separately to obtain uniform particle size. Sieving improved uniform mixing and enhanced the consistency of the formulation preparation. [46]

Step 2: Preparation of Powder Mixture

Accurately weighed quantities of coconut shell powder, activated charcoal, and neem powder were transferred into a clean mortar and mixed thoroughly to obtain a homogeneous blend. Coconut shell powder served as the combustible base material, while activated charcoal improved ignition and burning characteristics of the fumigant. Neem powder was incorporated due to its well-known herbal mosquito repellent activity. [47]

Step 3: Preparation of Binding Paste

Starch was dispersed in warm distilled water with continuous stirring to prepare a smooth binding paste. The prepared starch paste provided cohesiveness and helped in maintaining the structural integrity of the fumigant during molding and drying. [48]

Fig No.05 Ingredients for herbal mosquito repellent fumigant in powder form

Step 4: Incorporation of Eucalyptus Oil

Eucalyptus oil was added slowly to the powder mixture with continuous mixing to ensure uniform distribution throughout the formulation. The volatile oil imparted aromatic fragrance and contributed additional mosquito repellent activity due to the presence of bioactive constituents. [49]

Step 5: Formation of Dough Mass

The prepared starch paste was added gradually to the powder mixture and kneaded properly until a semi-solid dough-like consistency was achieved. Proper kneading ensured uniform distribution of ingredients and improved the molding characteristics of the preparation. [46,50]

Step 6: Shaping and Drying

The prepared mass was manually molded into cone-shaped fumigants and dried at room temperature for 24–48 hours until complete hardening was achieved. The dried fumigants were then stored in airtight containers to protect them from moisture and loss of volatile components before evaluation studies. [47,50]

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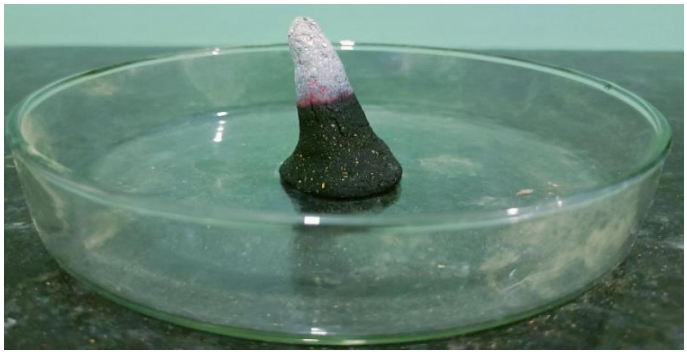
Table No.01 Composition of Eco-Friendly Herbal Mosquito Repellent

Ingredient	Function	Approx.quantity
Neem powder	Mosquito repellent herb	40g
Coconut shell powder	Base material for burning	25g
Activated charcoal powder	Helps combustion	15g
Starch	Binder	10g
Eucalyptus oil	Repellent fragrance	5ml
Water	For base formation	q.s

Evaluation Parameters

Burning Time

The burning time of the prepared herbal mosquito repellent fumigant was determined by igniting the fumigant carefully and recording the total time required for complete combustion using a stopwatch. Burning time is considered an important parameter for evaluating combustion efficiency and uniform burning behavior of herbal fumigant formulations. [51] A fumigant with optimum burning time provides prolonged release of herbal smoke and improves mosquito repellent activity in the surrounding environment. [52] Uniform and continuous burning also indicates proper blending and suitable binding characteristics of formulation ingredients. [53,54]



Fig, No.06 Burning Herbal Mosquito Repellent Fumigant

Smoke Density

Smoke density was evaluated by visual observation of the amount and continuity of smoke generated during combustion of the fumigant. Moderate smoke production is necessary for proper dispersion of active phytoconstituents responsible for mosquito repellency. [55] The presence of neem powder and eucalyptus oil contributed to characteristic aromatic smoke during burning. [56] Excessively dense smoke may cause irritation to users, whereas insufficient smoke generation may reduce repellent efficiency of the fumigant preparation. [57] Therefore, balanced smoke production is considered an essential quality parameter for herbal mosquito repellent formulations. [58]

Ash Value

Ash value was determined by collecting and weighing the residual ash remaining after complete combustion of the fumigant. Evaluation of ash content provides information regarding combustion characteristics and inorganic residue formation of the preparation. [59] Lower ash residue indicates cleaner and more efficient burning properties of the fumigant formulation. [60] The ash value also reflects the quality and proportion of combustible materials such as coconut shell powder and activated charcoal used during preparation. [61] Determination of ash value is important for assessing the overall performance and user acceptability of herbal fumigants. [62]

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Mosquito Repellent Test

The mosquito repellent activity of the prepared fumigant was evaluated by burning the formulation in a closed environment containing mosquitoes and observing mosquito activity before and after fumigation. Reduction in mosquito movement and presence indicated effective mosquito repellent action of the herbal formulation. [63] Neem powder and eucalyptus oil contributed significantly to the repellency due to the presence of volatile phytoconstituents possessing insect repellent properties. [64] Gradual dispersion of herbal smoke throughout the surrounding area enhanced the effectiveness of the fumigant preparation. [65] This evaluation helped in determining the practical applicability and mosquito repellent efficiency of the ecofriendly herbal fumigant. [66]

Stability Study

The stability study of the prepared herbal mosquito repellent fumigant was carried out by storing the formulation at room temperature and observing it periodically for physical changes such as cracks, hardness, color, odor, and moisture absorption. [67] Stability testing is important for determining the ability of the formulation to maintain its physical characteristics and performance during storage conditions. [68] The prepared fumigant remained stable without significant changes in appearance, aroma, or burning properties during the study period. [69] Proper drying and storage in airtight containers helped in maintaining the integrity and effectiveness of the herbal fumigant formulation over time. [70]

IV. RESULTS

Table No.02 Observation Table For Evaluation Parameters Of Eco-Friendly Herbal Mosquito Repellent Fumigant

Sr.No	Evaluation parameters	Observation	Results
1)	Burning Time	The prepared fumigant burned uniformly for approximately 25-30 minutes without interruption.	Indicates good combustion efficiency and prolonged mosquito repellent activity.
2)	Smoke Density	Moderate and continuous aromatic smoke was produced during combustion.	Suitable smoke generation for effective dispersion of herbal repellent constituents.
3)	Ash Value	Small quantity of greyish ash residue remained after complete burning.	Shows satisfactory burning characteristics with low residue formation.
4)	Mosquito Repellent Test	Significant reduction in mosquito activity was observed after fumigation in a closed environment.	Demonstrates effective mosquito repellent activity of the herbal fumigant .
5)	Stability Test	Except small cracks on surface, No significant changes in color, odor, hardness or burning property was observed during storage.	Formulation remained physically stable under room temperature conditions.

Discussion

The present study was carried out to prepare and evaluate an eco-friendly herbal mosquito repellent fumigant using neem powder, coconut shell powder, activated charcoal, starch, and eucalyptus oil. The prepared fumigant showed satisfactory physical characteristics with proper shape, hardness, and uniformity, indicating effective binding and formulation properties. The use of starch and gum tragacanth contributed significantly to the cohesiveness and structural stability of the fumigant preparation. [71]

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The burning behavior of the prepared fumigant was found to be satisfactory with uniform and continuous combustion. Coconut shell powder and activated charcoal played an important role in improving ignition and sustaining combustion for an adequate period of time. [72] The fumigant produced moderate smoke density, which was considered suitable for effective dispersion of herbal constituents without causing excessive irritation to the user. [73] The characteristic aromatic odor observed during burning was mainly due to eucalyptus oil, which enhanced the acceptability of the formulation. [74]

Ash value determination indicated comparatively low residue formation after complete combustion, suggesting efficient burning characteristics of the formulation. [75] The mosquito repellent test demonstrated noticeable reduction in mosquito activity after fumigation. This repellent activity may be attributed to the presence of bioactive phytoconstituents present in neem powder and eucalyptus oil, which possess natural insect repellent properties. [76,77]

The prepared herbal fumigant remained physically stable during the storage period without significant changes in color, odor, hardness, or burning characteristics. [78] Proper drying and airtight storage helped in maintaining the quality and stability of the formulation. [79] Overall, the study suggests that the prepared eco-friendly herbal mosquito repellent fumigant can serve as a safer and environmentally friendly alternative to synthetic mosquito repellents. [80]

Future Scope

The prepared eco-friendly herbal mosquito repellent fumigant demonstrates considerable potential for future research, product development, and commercial application. With increasing concern regarding the harmful effects of synthetic mosquito repellents, herbal fumigants

prepared from natural ingredients may emerge as safer and environmentally sustainable alternatives for domestic mosquito control. Future investigations may focus on formulation standardization to achieve improved burning efficiency, controlled smoke release, enhanced fragrance retention, and prolonged mosquito repellent activity. Incorporation of additional herbal essential oils and plant-derived bioactive constituents may further enhance the effectiveness and acceptability of the formulation. Advanced phytochemical, analytical, and toxicological studies can be carried out to evaluate safety, efficacy, and stability under different storage conditions. Development of improved shaping techniques, eco-friendly packaging systems, and large-scale manufacturing processes may support commercialization of the product. Therefore, the present formulation possesses promising future scope as an affordable, biodegradable, user-friendly, and eco-conscious herbal mosquito repellent system for public health protection.

V. CONCLUSION

The present study successfully demonstrated the preparation and evaluation of an eco-friendly herbal mosquito repellent fumigant using natural ingredients such as neem powder, coconut shell powder, activated charcoal, starch, gum tragacanth, and eucalyptus oil. The formulated fumigant exhibited satisfactory physical characteristics with proper shape, stability, and uniform burning behavior. Moderate smoke production and acceptable ash content indicated efficient combustion properties of the formulation. The mosquito repellent test revealed noticeable reduction in mosquito activity, which may be attributed to the presence of bioactive phytoconstituents in neem and eucalyptus oil. The prepared fumigant also remained stable during the storage period without significant changes in its physical properties. The study suggests that the developed herbal fumigant can serve as a safer, cost-effective, and environmentally friendly alternative to synthetic mosquito repellents. Therefore, the formulation possesses promising potential for domestic mosquito control with reduced environmental and health-related concerns.

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