ECO-GUARD: Development And Evaluation Of Herbal Mosquito Repellent Stick And Stored Grain Insect Repellent

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ABSTRACT

The present study focused on the formulation and evaluation of an eco-friendly mosquito repellent stick and insect repellent powder using selected herbal ingredients. The formulations contained Azadirachta indica, Ocimum sanctum, Acorus calamus, Commiphora wightii, camphor, essential oils, and natural binders. Mosquito repellency and behavioural responses were evaluated, along with insect repellent and insecticidal activity against Sitophilus spp. Physicochemical analysis of the mosquito repellent stick revealed low moisture content (0.63%) and ash value (0.45%), with a uniform burning time of 19.66 minutes and acceptable odour and smoke characteristics without causing suffocation or irritability. The herbal formulation showed a maximum mosquito repellency of approximately 57% at 3% concentration, while the same treatment exhibited a highest mortality of 60% against stored grain insects after 15 days of exposure. These findings indicate the potential applicability of the developed herbal formulations as biodegradable alternatives for mosquito control and stored grain protection.

Keywords: Herbal mosquito repellent, eco-friendly formulation, mosquito repellence, Sitophilus spp., insecticidal activity

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INTRODUCTION

Mosquitoes and stored grain insect pests are among the most significant vectors and agents responsible for public health problems and post-harvest agricultural losses worldwide. Mosquitoes serve as vectors for several life-threatening diseases, including malaria, dengue fever, chikungunya, yellow fever, Japanese encephalitis, and lymphatic filariasis, affecting millions of people annually, particularly in tropical and subtropical regions. According to global health reports, vector-borne diseases account for a considerable proportion of infectious diseases and continue to pose a major burden on healthcare systems. Simultaneously, insect infestation during grain storage leads to substantial quantitative and qualitative losses in cereals, pulses, and other food commodities. Stored grain pests such as *Sitophilus* species (rice weevil and maize weevil) damage grains by feeding and reproduction, resulting in weight loss, deterioration of nutritional quality, contamination, and reduced market value. Consequently, the development of safe, economical, and

environmentally sustainable pest management strategies has become an important area of research.[1]

Synthetic chemical insecticides and mosquito repellents have been widely employed for controlling disease vectors and storage pests due to their rapid effectiveness. Products containing pyrethroids, organophosphates, carbamates, and other synthetic compounds are extensively used in households and agricultural storage facilities. Although these chemicals provide immediate control, their continuous and indiscriminate use has resulted in several adverse consequences. The emergence of insecticide-resistant mosquito populations and storage pests has reduced the effectiveness of conventional chemical control measures. Moreover, prolonged exposure to synthetic insecticides has been associated with environmental pollution, contamination of soil and water resources, toxic residues in food grains, adverse effects on non-target organisms, and potential health hazards such as skin irritation, respiratory disorders, allergic reactions, and neurological complications in humans. Increasing awareness regarding these concerns has encouraged researchers to explore safer and eco-friendly alternatives derived from natural resources.[2]

Herbal formulations have emerged as promising substitutes for synthetic insecticides because of their biodegradability, low mammalian toxicity, renewable availability, and broad spectrum of biological activities. Medicinal plants have been utilized for centuries in traditional systems of medicine and household pest control due to their insecticidal, repellent, antimicrobial, antifungal, and antioxidant properties. Plant-derived bioactive compounds such as alkaloids, terpenoids, flavonoids, phenolics, tannins, and essential oils interfere with insect feeding, reproduction, growth, and host-seeking behaviour while exhibiting minimal harmful effects on humans and the environment. The use of herbal products aligns with sustainable agricultural practices and integrated pest management strategies by reducing dependence on synthetic chemicals and minimizing ecological damage.[2,3]

Among the medicinal plants investigated for insect repellent activity, *Azadirachta indica* (Neem) is considered one of the most effective botanical insecticides. Neem contains biologically active compounds such as azadirachtin, salannin, nimbin, and meliantriol, which possess insect repellent, antifeedant, ovicidal, larvicidal, and growth-regulating properties. These compounds disrupt insect hormonal systems, inhibit feeding behaviour, and reduce reproduction without causing severe environmental toxicity. Similarly, *Ocimum sanctum* (Holy Basil or Tulsi) is rich in volatile oils including eugenol, methyl eugenol, linalool, and cineole, which exhibit strong mosquito repellent and antimicrobial activities. The pleasant aroma of Tulsi also enhances user acceptability in herbal formulations.

Acorus calamus (Sweet Flag) has traditionally been used for protecting stored grains against insect infestation due to the presence of β-asarone and other aromatic constituents possessing insecticidal and repellent activities. These phytochemicals affect the nervous system of insects and reduce feeding and reproductive capacity. Likewise, *Commiphora wightii* (Guggul), a medicinal resin obtained from the plant, contains essential oils and resinous compounds with antimicrobial, fumigant, and insect repellent properties. The aromatic smoke generated from burning Guggul has traditionally been employed in households for purification and insect deterrence.

Camphor is another widely recognized natural insect repellent obtained either naturally or through purification processes. Owing to its high volatility, camphor releases aromatic vapours that interfere with insect orientation and host detection, thereby reducing mosquito landing and stored grain insect infestation. Essential oils extracted from aromatic plants further contribute to insect repellency through their volatile constituents, while natural binders such as starches and plant gums improve the structural integrity and burning characteristics of herbal mosquito repellent sticks without introducing harmful synthetic additives.[3,4]

The effectiveness of herbal mosquito repellents depends not only on their biological activity but also on their physicochemical characteristics. Parameters such as moisture content, ash value, burning time, smoke production, fragrance, and user acceptability significantly influence product quality and consumer satisfaction. Low moisture content enhances shelf life by preventing microbial growth and ensuring stable combustion. Controlled burning time ensures prolonged release of volatile bioactive compounds responsible for mosquito repellency, whereas acceptable smoke density minimizes respiratory discomfort and eye irritation commonly associated with conventional mosquito coils. Therefore, comprehensive physicochemical evaluation is essential for developing standardized and efficient herbal formulations suitable for household use.

Similarly, the evaluation of herbal insect repellents for stored grain protection involves the assessment of repellency, mortality, and behavioural responses of storage pests. Effective herbal powders or formulations should reduce insect infestation while preserving grain quality without leaving toxic residues. Plant-derived repellents may function through multiple mechanisms, including masking host odours, disrupting insect sensory

receptors, reducing feeding activity, impairing reproduction, and causing mortality through neurotoxic or physiological effects. These multifunctional actions make botanical formulations valuable components of integrated pest management programmes aimed at sustainable food storage.[4]

Recent scientific investigations have increasingly focused on combining multiple medicinal plants to achieve synergistic effects. The combination of neem, tulsi, sweet flag, guggul, camphor, and essential oils may provide enhanced repellent and insecticidal activity compared with individual plant extracts because each ingredient contributes distinct bioactive compounds targeting different physiological pathways in insects. Furthermore, the incorporation of biodegradable and renewable plant materials supports environmentally responsible product development while reducing the ecological footprint associated with chemical pesticides.[3,4]

In the present study, an eco-friendly herbal mosquito repellent stick and a stored grain insect repellent powder were formulated using selected medicinal plants and natural ingredients. The mosquito repellent stick was evaluated for physicochemical parameters including moisture content, ash value, burning time, smoke characteristics, odour, and user acceptability, along with mosquito repellency under controlled conditions. The stored grain insect repellent formulation was assessed for repellent efficacy and insecticidal activity against *Sitophilus* species over a defined exposure period. By integrating traditional botanical knowledge with scientific evaluation, this study aims to develop biodegradable, safe, cost-effective, and environmentally sustainable alternatives for household mosquito control and stored grain protection. The findings may contribute to the growing body of evidence supporting the application of herbal formulations in public health, agriculture, and integrated pest management while promoting reduced dependence on synthetic chemical pesticides.[4]

MATERIALS AND METHODS

1. Neem Leaf Powder (Azadirachta indica)

Neem (*Azadirachta indica* A. Juss.) belongs to the family Meliaceae and is one of the most extensively studied medicinal plants due to its broad-spectrum insecticidal properties. The leaves contain several biologically active compounds, including azadirachtin, nimbin, salannin, gedunin, and quercetin, which exhibit insecticidal, antifeedant, ovicidal, and growth-regulating activities. In the present formulation, neem leaf powder was incorporated as the principal insecticidal component. In the mosquito repellent stick, neem releases bioactive volatile compounds upon burning, which interfere with mosquito olfactory receptors and reduce mosquito landing and biting. The smoke generated also possesses larvicidal and repellent properties. In the stored grain insect repellent formulation, neem acts as a natural insecticide by inhibiting feeding, oviposition, and larval development of *Sitophilus* spp., thereby minimizing grain damage and infestation. Its biodegradable nature and low toxicity make it an ideal alternative to synthetic insecticides.[4,5]

2. Tulsi Leaf Powder (Ocimum sanctum)

Tulsi (*Ocimum sanctum* Linn.), also known as Holy Basil, belongs to the family Lamiaceae and is valued for its medicinal and aromatic properties. The leaves are rich in essential oils containing eugenol, methyl eugenol, linalool, cineole, and ursolic acid, which possess antimicrobial, antioxidant, and insect-repellent activities. In this study, tulsi leaf powder was incorporated into the herbal formulation. During combustion, tulsi releases aromatic volatile compounds that effectively repel mosquitoes while imparting a pleasant fragrance to the repellent stick. Additionally, its antimicrobial activity helps inhibit microbial growth on stored grains, thereby improving grain quality. Tulsi also exhibits mild insect-repellent activity against storage pests, contributing to the overall efficacy of the stored grain insect repellent.[5]

3. Guggul Resin (Commiphora wightii)

Guggul is a natural oleo-gum resin obtained from *Commiphora wightii*, a medicinal plant belonging to the family Burseraceae. The resin contains bioactive compounds such as guggulsterones, terpenoids, sesquiterpenes, and volatile essential oils that exhibit antimicrobial, fumigant, and insect-repellent properties.guggul resin were added to the formulation to serve primarily as a natural fumigant. During burning, guggul produces aromatic smoke rich in volatile compounds that repel mosquitoes and enhance the persistence of the repellent effect. In the stored grain insect repellent, the volatile constituents create an unfavorable atmosphere for insect survival, reducing insect movement and infestation. Furthermore, guggul contributes to the characteristic pleasant aroma of the herbal formulation.

4. Vacha Rhizome Powder (Acorus calamus)

Vacha (*Acorus calamus* Linn.), commonly known as Sweet Flag, belongs to the family Acoraceae. The rhizome contains several biologically active constituents, including β-asarone, α-asarone, acorenone, and essential oils, which possess insecticidal, fumigant, and repellent properties. In this formulation, vacha rhizome powder was incorporated due to its strong insecticidal activity. During burning, the aromatic volatile compounds

released from the rhizome interfere with mosquito sensory receptors, reducing mosquito attraction toward humans. In stored grain protection, vacha acts as both a contact insecticide and fumigant against *Sitophilus* spp., disrupting normal physiological functions, reducing feeding activity, and increasing insect mortality. Its natural origin and broad-spectrum activity make it a valuable ingredient in botanical pest management.

5. Camphor Powder

Camphor is a naturally occurring crystalline compound primarily obtained from the wood of *Cinnamomum camphora* and is widely recognized for its strong aromatic and insect-repellent properties. It consists mainly of camphor, along with smaller amounts of borneol and cineole. In the present study, camphor powder was incorporated into the formulation. Camphor volatilizes rapidly during combustion, producing vapours that effectively repel mosquitoes by interfering with their host-seeking behavior. Additionally, it enhances the ignition and burning characteristics of the mosquito repellent stick, ensuring uniform combustion and sustained release of active herbal ingredients. In the stored grain insect repellent formulation, camphor vapours act as a fumigant that discourages insect infestation and movement within stored grains.[5]

6. Essential Oil

Essential oils are concentrated volatile plant extracts obtained from aromatic plants such as citronella, lemongrass, eucalyptus, peppermint, and lavender. These oils are rich in bioactive compounds including citronellal, citronellol, geraniol, limonene, citral, and eucalyptol, which exhibit excellent mosquito-repellent and insecticidal properties. In this study, essential oil was incorporated into the formulation as the primary active repellent ingredient. During burning, the volatile compounds evaporate into the surrounding air, masking human odours and disrupting mosquito olfactory receptors, thereby preventing mosquito bites. In the stored grain insect repellent, essential oils exhibit fumigant toxicity, reduce insect feeding and reproduction, and enhance the overall repellent efficacy of the formulation.[6]

7. Charcoal Powder

Charcoal powder is a carbon-rich material produced by the controlled combustion of plant biomass under limited oxygen conditions. Although it possesses little direct insecticidal activity, it plays a vital role in the physical properties of the mosquito repellent stick. In the present formulation, of charcoal powder was incorporated as the primary base material. Charcoal facilitates easy ignition, provides sustained combustion, maintains structural integrity, and ensures uniform burning throughout the duration of use. It also contributes to the formation of stable ash after combustion. In the stored grain insect repellent formulation, charcoal functions mainly as an inert carrier that helps distribute the active herbal ingredients uniformly without affecting grain quality.[7]

8. Cow Dung Powder

Cow dung is a traditional natural material composed of partially digested plant fibres, cellulose, lignin, minerals, and organic matter. It has been widely used in rural households for preparing herbal incense and mosquito repellent products because of its excellent binding and combustion properties. In this study, cow dung powder was used as a natural binder in the mosquito repellent stick formulation. It improves the mechanical strength of the stick, facilitates slow and uniform burning, and contributes to consistent smoke generation during combustion. Although cow dung has limited direct insecticidal activity, its role in maintaining the structural stability and burning efficiency of the formulation is essential. It is generally not used as an active ingredient in stored grain protection but serves as a biodegradable and eco-friendly base material.

9. Lantana Leaf Powder (Lantana camara)

Lantana camara L., belonging to the family Verbenaceae, is a medicinal shrub known for its insecticidal and repellent properties. The leaves contain several bioactive compounds, including lantadenes, flavonoids, triterpenoids, alkaloids, and phenolic compounds, which exhibit toxic effects against various insect species. In the present formulation, lantana leaf powder was incorporated as an additional botanical insecticide. During combustion, the volatile constituents released from the leaves contribute to mosquito repellency by masking host odours and disrupting mosquito orientation. In the stored grain insect repellent formulation, lantana leaf powder acts as a natural insecticide by reducing feeding, inhibiting reproduction, and increasing mortality of *Sitophilus* spp. Its synergistic interaction with neem, vacha, and essential oils enhances the overall effectiveness of the herbal formulation while providing an environmentally friendly alternative to synthetic pesticides.[8]

EXPERIMENTAL WORK

Formula for Dhoop sticks

Table 1. Mosquito and insect repellent formula

Ingredients	Quantity (g)	Property
Neem leaf powder	15	Insecticidal
Tulsi leaf powder	10	Anti-microbial
Guggul resin	8	Fumigant
Vacha rhizome powder	5	Insecticidal
Camphor powder	5	Enhances burning
Essential oil	2 (ml)	Mosquito repellent
Charcoal	17.5	Base / binder
Cow dung	17.5	Base / binder
Lantana camara leaf powder	15	Insecticidal

Preparation of herbal mosquito repellent stick and stored grain insect repellent

The herbal mosquito repellent stick and stored grain insect repellent were prepared using selected medicinal plant powders, natural binders, and essential oil. Initially, fresh neem leaves (*Azadirachta indica*), tulsi leaves (*Ocimum sanctum*), lantana leaves (*Lantana camara*), vacha rhizomes (*Acorus calamus*), and guggul resin (*Commiphora wightii*) were collected, cleaned thoroughly to remove dust and foreign matter, and shade-dried at room temperature until a constant weight was achieved. The dried plant materials were then pulverized separately using a laboratory grinder to obtain fine powders.[9,10]

The powdered herbal ingredients were passed through an **80-mesh sieve** to obtain a uniform particle size, ensuring better mixing and homogeneous distribution of the active constituents in the final formulation. The sieved powders were weighed accurately according to the required formulation composition. Neem leaf powder (15 g), tulsi leaf powder (10 g), guggul resin (8 g), vacha rhizome powder (5 g), camphor powder (5 g), lantana leaf powder (15 g), charcoal powder (17.5 g), and cow dung powder (17.5 g) were transferred into a clean mixing bowl and blended thoroughly until a homogeneous dry mixture was obtained.11

Approximately **2 ml of essential oil** was added gradually to the dry mixture. Small quantities of distilled water were then incorporated while continuously kneading until a smooth, uniform, and non-sticky dough of suitable consistency was formed. Care was taken to avoid excess water, as it could adversely affect the shape and burning characteristics of the mosquito repellent stick. For the **mosquito repellent stick**, the prepared dough was manually rolled or moulded into cylindrical sticks of uniform length and diameter. The sticks were dried under shade for **48–72 hours** or until complete removal of moisture was achieved. After drying, the sticks were stored in airtight containers at room temperature until further physicochemical evaluation and mosquito repellency studies.[12]

For the **stored grain insect repellent**, the prepared herbal powder mixture was packed directly into small porous sachets (pouches) made of muslin cloth or non-woven fabric. Each pouch contained a predetermined quantity of the herbal formulation and was sealed properly. The pouches were then placed inside grain storage containers for evaluating their repellent and insecticidal efficacy against *Sitophilus* spp. Alternatively, the herbal powder could be mixed directly with stored grains at the desired concentration for laboratory bioassays. The prepared mosquito repellent sticks were subsequently evaluated for physicochemical parameters, including moisture content, ash value, burning time, smoke characteristics, and organoleptic properties. Both the mosquito repellent sticks and stored grain insect repellent pouches were further subjected to biological evaluation to determine their mosquito repellency, insect repellent activity, and insecticidal efficacy under laboratory conditions.[13,14]

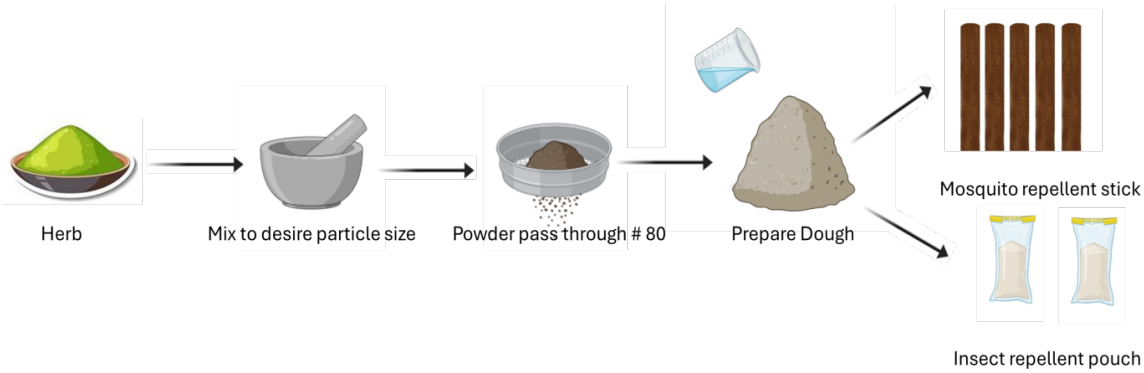


Fig. 1. Schematic representation of the preparation of herbal mosquito repellent stick and insect repellent pouch

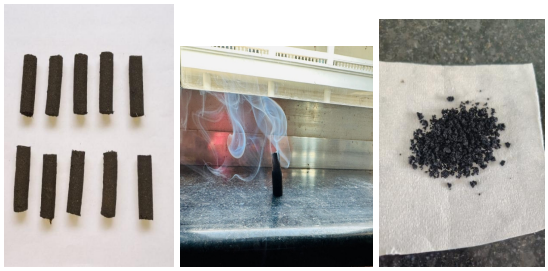


Fig. 2. Photographs of the prepared herbal formulations

Evaluation of mosquito killing and repellent activity of Dhoop sticks

1.Organoleptic characters: - Colour, odour and appearance by using visual inspection.15

2.Moisture content: - The initial weight of the prepared Dhoop was ignited and also the final weight of the dried Dhoop was noted.15,16

3. Ash value: - The Dhoop stick was burnt completely and the ash was collected and weighed.16



Fig. 3. Ash obtained after complete burning of the Dhoop stick

4. Irritability Test: - The irritability test is performed to check that whether the prepared the Dhoop cause any irritation to the skin [16,17]

Repellency test

Repellency test performed in a net of cuboidal shape with an opening so that the mosquitoes can escape through. The Dhoop was burn inside the net. The times taken by the mosquitoes try to escape or to get number or to be killed should be noted.[17]

Evaluation of insect killing and repellent activity of the herbal pouch

Mortality test

In three 250 mL jars (experimental units), 100 g of corn previously exposed to the sun were placed. Subsequently, 1, 2, and 3 g of vegetable powder were added to each jar (1%, 2%, and 3% concentrations, respectively); it was shaken manually using oscillatory and vertical movements for 1 min until a homogeneous powder dispersion was achieved. Once the mixture was made, 20 specimens of adult *S. zamias* insects were placed in each jar without distinction of sex. Negative control was used without plant powder, and positive control with 0.0018 g of aluminium phosphide. This pesticide was used because it is the chemical product producers use in the community to control the weevil, and it has been used in other studies as a positive control where plant powders have also been evaluated .This insecticide is a fumigant tablet purchased in local stores. It comes in a tube with 20 tablets of 3 g each. The concentration of aluminium phosphide is 56%, equivalent to 560 g of A.I./kg, the recommended dose average in corn is 2 to 4 tablets/m3. The dose used in the experiment was calculated based on the average volume of corn contained in the jars (196 ± 8.9 cm3) from a dose of 3 tablets/m3 of aluminium phosphide (in the community, producers use arbitrary doses ranging from 2 to 4 tablets/ton/room), under the same conditions of quantity of corn and insects. This product is applied directly to the grains, and when it comes into contact with ambient humidity, it releases highly toxic phosphine gas, which is responsible for its insecticidal effect . Its effect is rapid, depending on humidity and temperature conditions (24 to 72 h), and its residue is a Gray powder that is apparently inert to humans and formed by aluminium hydroxide . Still, such residue could harm other organisms, such as earthworms . All jars were covered with organza fabric lids to allow aeration and prevent insect escape. The treatments were placed in a room for 15 days under the typical environmental conditions of temperature, humidity, and community light, separated at 1 m to avoid interaction between them. Exposure was defined for 15 days since the dust's action was slower than the chemical product. After 15 days, the number of dead adults in each treatment was quantified. The mortality percentage was obtained using the Abbott formula : % Corrected Mortality = $[(X - Y)/(100 - Y)] \times 100$, where X = % Mortality in powder treatment, Y = % Mortality in the negative control (without plant powder). An individual who was not mobile when using a source of heat and light (flashlight) for a minimum of 5 min was considered dead.[18]



Fig. 4. Experimental set-up for the mortality test against Sitophilus spp.

Repellency test (stored grain insects)

The devices were fabricated using three 250 mL transparent plastic cups connected at their base by a 20 cm long transparent plastic hose (Fig. 5). One hundred grams of corn were placed in each side glass (the central glass remained empty). Then, the plant powder was added to one of the glasses with corn, and it was shaken manually using oscillating and vertical movements for 1 min until a homogeneous dispersion of the powder was achieved. The other adjacent cup with corn served as a non-dust control treatment. One device was used per plant and concentration (1%, 2% and 3%). Once the devices were prepared, 30 food-deprived adult insects were released into the central vessel without distinction of sex, aged between 7 and 14 days. Immediately, all the glasses were covered with organza fabric to allow for ventilation and prevent insects from escaping. The devices were placed in the same room and separated at a distance of 1 m to avoid interaction between them. At 24 h after the release of the insects, the number of individuals in each glass was counted; with the values obtained, the repellency index (RI) was calculated using the formula RI = (2G)/(G + P), where G = number of insects in the treatment and P = number of insects in the control. The RI values range from zero to two to obtain the following classification: RI = 1 neutral effect, RI > 1 attracting effect, RI < 1 repellent effect.[19,20]



Fig. 5. Experimental set-up for the repellency test

Evaluation of mosquito repellent activity of Dhoop sticks using the mosquito cage method

Mosquitoes required for the evaluation activity of Dhoop stick were collected by the help of polyester mosquito net. In the evening time when the mosquitoes are highly active, the net was waved slowly around the damp areas and grass field to trap the mosquitoes. Then it was transferred to a case of size 70 cm X 70 cm. Around 50 mosquitoes were taken in the case at 6 - 9 PM. Two sticks of size 3 cm each were burned at two corners of room diagonally with sufficient ventilation. Case containing mosquitoes was kept at the centre of the room. The activity of mosquitoes was observed and noted for next three hours20

RESULTS AND DISCUSSION

Physicochemical evaluation

Organoleptic characters: Colour – black; odour – agreeable.

Moisture content: Moisture content (%) = [(Initial weight − Final weight) / Initial weight] × 100

Ash value: The weight of ash obtained was 0.45 g.

Table 2. Physicochemical evaluation of the herbal mosquito repellent stick

No.	Evaluation test	Result
1	Moisture content	6.30 ± 0.26%
2	Ash value	0.45 ± 0.01%
3	Burning time	19.66 ± 0.56 min
4	Odour	Agreeable
5	Smoke visibility	Average compared to standard
6	Suffocation	No
7	Irritability	No
8	Distance travelled after burning stick	Sufficient in a 10 × 12 feet room

Insecticidal effect

The 3% concentrations of the treatments with *C. ambrosioides* and *P. auritum* were statistically equal after 15 days of exposure, along with the control (aluminum phosphide 0.0018 g), presenting the highest average mortality rates (85.0%, 83.3%, and 100%, respectively) (Table 1). *O. vulgare* and *L. nobilis* at the same concentration of 3%, and *C. ambrosioides* and *P. auritum* at 2%, presented mortalities between 55.0% and 63.3%. The treatments of *O. vulgare* and *L. nobilis* at 2% and the four powders at 1% fluctuated between 21.7% and 36.7% mortality

Repellency effect

The treatments with 3% plant powders were statistically equal to each other and different from their corresponding control, showing the highest percentages of repellency between 61.0% and 89.7%. In general, powders at low concentrations (1% and 2%) presented an attractive to neutral effect (RI = 1.7 to 1.0), while for higher concentrations (3%), they presented a repellent effect (RI = 0.8 to 0.2). *L. nobilis* and *O. vulgare* powders stand out for their attractive effect at low concentrations, while *C. ambrosioides* and *P. auritum* powders stand out for their repellent effect at a 3% concentration

Mosquito repellent test evaluation



Fig. 6. Mosquito cage method used for evaluation of the Dhoop stick

The herbal mosquito-repellent stick was tested against 15 mosquitoes at a temperature of 22 °C for an exposure period of 35 minutes. The mean number of mosquitoes that escaped was 3.67 ± 0.58, while 11.67 ± 0.58 mosquitoes were found dead. The observed mosquitocidal activity was 77.80%, indicating considerable insecticidal activity of the formulation under the tested conditions. The mosquito-repellent activity was 17.67%, suggesting a comparatively lower repellency effect. The mean burning time of the herbal stick was 23.00 ± 2.65 minutes, indicating sustained burning and release of the volatile constituents during the test period.

Table 3. Mosquito repellent test of the herbal stick

No.	Report	Result
1	No. of mosquitoes	15 ± 0
2	No. of mosquitoes escaped	3.67 ± 0.58
3	No. of mosquitoes dead	11.67 ± 0.58
4	Time (min)	35 ± 0
5	Temperature	22 °C
6	Burning time (min)	23.00 ± 2.65
7	Mosquitocidal activity	77.80%
8	Mosquito repellent activity	17.67%

Mosquito repellent test at different locations

Test was done by simply selecting the mosquito prone areas in the evening and night period. For investigating mosquito repellent activity the prepared incense sticks are checked for causal effect such as irritation, coughing, and tears are observed and recorded.

Table 4. Mosquito repellent activity at different locations

Area	Observation	Remark
Lab corners	No irritation, mosquitoes removed from room	Mosquitoes are repelled
College premises	Smoke does not cause irritation; mosquitoes escaped	
Home	No irritation, mosquitoes escaped	

Evaluation of mosquito repellent activity after burning

Mosquito net method was used to evaluate the efficacy of Dhoop stick. Two Dhoop stick were burned completely in the room and Behavior of mosquito was observed for three hours. In between 7 to 8 pm 18 mosquitoes were aligned on the net and 7 mosquitoes were observed with knock down effect. In next hour number of mosquitoes (13.) were observed with knock down effect. Whereas, in next one hour the number of mosquitoes observed with knock down effect were increased from 18 to 33. Thus, formulated Dhoop sticks have showed promising mosquito repellent potential.

Table 5. Behaviour of mosquitoes after burning of Dhoop sticks

Mosquito behaviour	7 to 8 pm	8 to 9 pm	9 to 10 pm
Free movement	4	0	0
No. of mosquitoes aligned on window mosquito net	18	13	5
Struggling for life (paralysed)	3	2	1
Knock down effect (dead)	7	21	33

CONCLUSION

The herbal mosquito repellent stick showed acceptable physicochemical characteristics, with low moisture content and ash value, uniform burning time and satisfactory odour and smoke properties without suffocation or irritation. The formulation exhibited mosquito repellent and knock-down activity, and the herbal powder showed repellent and insecticidal activity against stored grain insects (Sitophilus spp.). The developed formulations may therefore serve as biodegradable, eco-friendly alternatives for household mosquito control and stored grain protection.

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