

Formulation and evaluation of mosquito repellent sticks using herbal powders of neem, tulasi, vasa (Sweet Flag), clove, and cinnamon

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Abstract

Background: Mosquitoes are primary vectors of life-threatening diseases such as malaria, dengue, chikungunya, and filariasis, especially in tropical and subtropical regions. Although chemical repellents are widely used, their associated health hazards and environmental impact necessitate safer alternatives.

Objective: This study aims to formulate and evaluate herbal mosquito repellent sticks using powders of *Azadirachta indica* (Neem), *Ocimum sanctum* (Tulasi), *Acorus calamus* (Sweet Flag), *Syzygium aromaticum* (Clove), and *Cinnamomum verum* (Cinnamon) and to assess their physical, combustion, and repellent properties.

Methods: Ten formulations were developed using various combinations of herbal powders and natural excipients. Each formulation was assessed for physical appearance, moisture content, irritability, suffocation, ash value, burning time, smoke visibility, and mosquito repellency in different indoor environments.

Results: All formulations were rod-shaped with smooth surfaces and characteristic herbal odors. Moisture content ranged from 0.5–2%, and no irritability or suffocation effects were observed. Burning time ranged from 15–30 minutes. High smoke visibility and significant mosquito repellent activity were noted, especially in formulations F4, F5, F9, and F10.

Conclusion: The developed herbal sticks showed promising potential as natural, non-toxic mosquito repellents. Their effectiveness, safety, and eco-friendly nature position them as viable alternatives to chemical repellents. Further field trials and phytochemical standardization are recommended.

Keywords: Mosquito repellent, herbal formulation, neem, tulasi, clove, sweet flag, cinnamon, vector control, eco-friendly repellent

Introduction

Mosquitoes are notorious vectors responsible for transmitting diseases such as malaria, dengue, chikungunya, and filariasis, posing a major public health challenge in tropical and subtropical regions [1]. Although chemical-based mosquito repellents are widely used, they often cause side effects like skin irritation, respiratory issues, and contribute to environmental toxicity [2,3]. Therefore, there is a growing demand for eco-friendly and herbal mosquito repellents that are biodegradable, non-toxic, and safe for human use [4, 5]. Plant-based mosquito repellents, particularly those made using *Azadirachta indica* (Neem), *Ocimum sanctum* (Tulasi), *Acorus calamus* (Sweet Flag), *Syzygium aromaticum* (Clove), and *Cinnamomum verum* (Cinnamon) have gained prominence due to their natural origin and therapeutic properties [6,7,8,9]. These herbs contain essential oils and active phytochemicals known for their insecticidal and repellent actions, interfering with mosquitoes' olfactory systems and deterring bites [6, 7]. Among different dosage forms, herbal mosquito repellent sticks are preferred because of their convenience, cost-effectiveness, longer action, and ability to release active compounds through slow combustion [4, 9]. The smoldering of these sticks emits volatile phytoconstituents into the environment, forming a protective barrier against mosquitoes without the need for synthetic agents [9, 10]. Numerous studies have demonstrated the effectiveness of polyherbal repellents, revealing synergistic outcomes when multiple botanicals are used together [5, 9]. In addition, formulation enhancements like binding agents and

combustion modifiers help improve product stability, burning characteristics, and overall repellent performance [9, 10]. The present study aims to formulate and evaluate mosquito repellent sticks using powdered forms of Neem, Tulasi, Sweet Flag, Clove and Cinnamon. The objective is to develop a sustainable, affordable, and effective herbal alternative to synthetic repellents, which may contribute to vector control strategies and reduce disease transmission in endemic regions. This research is expected to contribute to public health by offering a natural method to minimize mosquito bites and reduce disease transmission risk.



Fig 1: Adult female *Aedes mosquito*, a primary vector of malaria & dengue

Materials and Methods

Materials

The present study utilized herbal and natural ingredients known for their insect-repellent and combustion-supporting properties. The primary materials included Vasa (Sweet Flag), Clove, Neem, Tulasi, Cinnamon, Camphor, Starch, Eucalyptus oil, Sawdust, and Charcoal, all of which were procured from a local authentic store in Eluru, Andhra Pradesh. These ingredients were selected based on their traditional use, proven efficacy, and safety profile. Their incorporation into mosquito repellent stick formulations supports the development of an eco-friendly and sustainable alternative to synthetic repellents.

- 1. Vasa (Sweet Flag):** (*Acorus calamus*, family: Acoraceae) is a semi-aquatic perennial plant whose rhizome possesses aromatic and insect-repellent properties. Traditionally known as Calamus or Vacha, it is native to Asia and Europe and widely used in Ayurveda for respiratory and neurological conditions. In repellent formulations, it acts as a natural deterrent against insects due to its volatile oil content.
- 2. Clove:** (*Syzygium aromaticum*, family: Myrtaceae) is the dried flower bud of an evergreen tree native to Indonesia and now cultivated in several tropical regions. Known for its characteristic aroma and high eugenol content, clove offers antimicrobial, analgesic, and insect-repellent actions, making it a valuable ingredient in mosquito repellent sticks.
- 3. Neem:** (*Azadirachta indica*, family: Meliaceae) is a fast-growing tree native to South Asia. Various parts of the plant, especially leaves and seeds, possess bioactive compounds with proven insecticidal, antimicrobial, and therapeutic effects. Neem has been widely used to protect crops and homes from mosquitoes and other pests [11].
- 4. Tulasi:** (*Ocimum sanctum* or *O. tenuiflorum*, family: Lamiaceae), commonly known as Holy Basil, is an aromatic herb native to India and revered in traditional medicine. It contains essential oils such as camphene and eugenol, which exhibit insect-repelling and antifungal properties, making it suitable for herbal mosquito repellents.
- 5. Cinnamon:** (*Cinnamomum verum*, family: Lauraceae) is derived from the inner bark of tropical evergreen trees, primarily cultivated in Sri Lanka and India. Known for its warm aroma and antimicrobial effects, cinnamon also contributes natural insect-repellent properties due to the presence of cinnamaldehyde.
- 6. Camphor:** (*Cinnamomum camphora*, family: Lauraceae) is obtained from the wood of the camphor tree and is widely used in religious and medicinal practices. It acts as a natural insect deterrent and enhances the burning quality of sticks by releasing a strong fragrance upon combustion.
- 7. Starch:** a polysaccharide extracted from sources such as corn, potato, or tapioca, was used in this study as a binder to provide structural integrity to the sticks. It

helps maintain cohesion among powdered herbal ingredients and supports slow combustion.

- 8. Eucalyptus oil:** extracted from the leaves of *Eucalyptus globulus* (family: Myrtaceae), is a volatile essential oil known for its sharp, refreshing odor and insecticidal action. Rich in eucalyptol (1,8-cineole), it offers repellent and antimicrobial effects, contributing to both efficacy and fragrance [12].
- 9. Sawdust:** a by-product of wood processing, served as a combustible base in the formulation. It facilitates even burning and helps release herbal vapors efficiently. Its fine texture allows easy mixing with other ingredients.
- 10. Charcoal:** produced from pyrolyzed wood or coconut shell, was included as a combustion enhancer. It helps prolong the burning time of the sticks and ensures a steady release of active herbal fumes while minimizing smoke and soot.

Methods

Standardized Method for the Preparation of Herbal Powders

All powdered ingredients used in the mosquito repellent stick formulation namely Neem (*Azadirachta indica*), Tulasi (*Ocimum tenuiflorum*), Sweet Flag (*Acorus calamus*), Clove (*Syzygium aromaticum*), Cinnamon (*Cinnamomum verum*), Camphor (*Cinnamomum camphora*), Starch, Sawdust, and Charcoal were prepared using standard methods to ensure quality and uniformity. Plant-based materials such as neem, tulasi, sweet flag, clove, and cinnamon were selected fresh, washed thoroughly with clean water to remove dirt and impurities, and dried in a shaded, well-ventilated area for several days until completely moisture-free. The dried materials were then ground into a fine powder and passed through a sieve to obtain uniform particle size. Dry commercial ingredients like camphor, starch, sawdust, and charcoal, which are typically available in clean, processed form, were used directly or ground if needed and similarly passed through a sieve to ensure consistent texture. Eucalyptus oil and perfume (rose oil) were used directly in liquid form during the formulation process without any prior drying or modification. All prepared powders were stored in airtight containers in a cool, dry environment to preserve their functional properties. This method supports the retention of the plant's natural oils and active compounds, ensuring their effectiveness in the final repellent product [6, 7, 13].

Preparation of Mosquito Repellent Sticks

Herbal mosquito repellent sticks were formulated according to the ingredient compositions outlined in formulations F1 to F10, as detailed in Table 1. The preparation process began with blending the specified quantities of dry powdered ingredients namely neem, tulasi, clove, vasa, cinnamon, camphor, starch, sawdust, and charcoal in a clean, dry mortar. The powders were thoroughly homogenized to ensure a uniform mixture. Subsequently, measured amounts of Eucalyptus oil and rose oil (perfume) were gradually incorporated to facilitate the even distribution of volatile constituents. Distilled water was then added incrementally to achieve a cohesive, moldable paste. This semi-solid mass was manually packed into cylindrical

molds, typically made from papaya stems or equivalent alternatives. After an initial phase of air drying, the molded sticks were subjected to oven drying at 50–60 °C for approximately 30 minutes to enhance mechanical integrity and ensure complete moisture removal. Once dried, the

sticks were demolded and stored in airtight, moisture-resistant containers at ambient temperature to preserve their bioactive properties and maintain formulation stability for further evaluation [14].



Fig 2: Materials used for Formulations of Mosquito Repellent Sticks

Table 1: Formulation of Herbal Mosquito Repellent Sticks (F1 to F10)

| S. No | Ingredients | F1 | F2 | F3 | F4 | F5 | F6 | F7 | F8 | F9 | F10 |
|-------|--------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| 1 | Neem | 10 gm | – | – | – | 2.5 gm | 10 gm | – | – | – | 2.5 gm |
| 2 | Tulasi | – | 10 gm | – | – | 2.5 gm | – | 10 gm | – | – | 2.5 gm |
| 3 | Clove | – | – | 10 gm | – | 2.5 gm | – | – | 10 gm | – | 2.5 gm |
| 4 | Vasa (Sweet Flag) | – | – | – | 10 gm | 2.5 gm | – | – | – | 10 gm | 2.5 gm |
| 5 | Camphor | 1.5 gm | 1.5 gm | 1.5 gm | 1.5 gm | 1.5 gm | 1.5 gm | 1.5 gm | 1.5 gm | 1.5 gm | 1.5 gm |
| 6 | Cinnamon | 2 gm | 2 gm | 2 gm | 2 gm | 2 gm | 2 gm | 2 gm | 2 gm | 2 gm | 2 gm |
| 7 | Charcoal | 1 gm | 1 gm | 1 gm | 1 gm | 1 gm | – | – | – | – | – |
| 8 | Sawdust | – | – | – | – | – | 1 gm | 1 gm | 1 gm | 1 gm | 1 gm |
| 9 | Eucalyptus Oil | 1 ml | 1 ml | 1 ml | 1 ml | 1 ml | 1 ml | 1 ml | 1 ml | 1 ml | 1 ml |
| 10 | Starch | 2 gm | 2 gm | 2 gm | 2 gm | 2 gm | 2 gm | 2 gm | 2 gm | 2 gm | 2 gm |
| 11 | Perfume (Rose Oil) | 1 ml | 1 ml | 1 ml | 1 ml | 1 ml | 1 ml | 1 ml | 1 ml | 1 ml | 1 ml |
| 12 | Water | q.s. | q.s. | q.s. | q.s. | q.s. | q.s. | q.s. | q.s. | q.s. | q.s. |



Fig 3: Formulation of Mosquito Repellent Sticks

Evaluation Tests

1. Physical Appearance

The prepared herbal mosquito repellent sticks were evaluated for their colour, odour, size, shape, texture, homogeneity, and physical state. These observations were made through direct visual and olfactory inspection [15].

2. Flammability and Burning Time

To assess flammability, a stick was ignited and observed for flame propagation and smoke production. The burning time, recorded until the stick was fully consumed, was found to be approximately 24 minutes, indicating efficient combustion with minimal smoke. Variations in burning time are influenced by stick length, diameter, and formulation quality [15].

3. Ash Value

The completely burned residue of the sticks was collected and weighed to determine the ash content, which reflects the inorganic residue post-combustion [16].

4. Moisture Content

The moisture content was assessed by comparing the initial and final weights of the dried herbal sticks after oven

drying. This test ensures the product's shelf stability and resistance to microbial growth.

5. Mosquito Repellent Activity Test

The repellent activity was evaluated in situ by placing the sticks in mosquito-prone environments during evening and night. Locations included laboratory corners, near shrubs, and public areas like the cafeteria. Observations were made on mosquito presence before and after burning, and public feedback was documented [17].

6. Smoke Toxicity Test

To test for smoke toxicity, mosquitoes were attracted into a chamber using worn socks and then exposed to the smoke of a burning stick for 45 minutes. Mortality was recorded at 15-minute intervals to assess the lethal impact of the smoke [14].

7. Smoke Visibility Test

The density and visibility of smoke from the sticks were evaluated visually upon ignition. Observations were made on smoke spread, thickness, and irritation potential, compared across formulations [14].

8. Irritability or Odour Assessment

The incense sticks were assessed for olfactory acceptability and potential irritant effects on the eyes or throat during burning. The test was aimed at ensuring user comfort and sensory tolerability [18].

9. Suffocation Test

A suffocation potential assessment was conducted in a confined space to evaluate whether the smoke caused discomfort or hazardous conditions due to poor ventilation. This test ensured that smoke levels remained within safe inhalation limits [19].

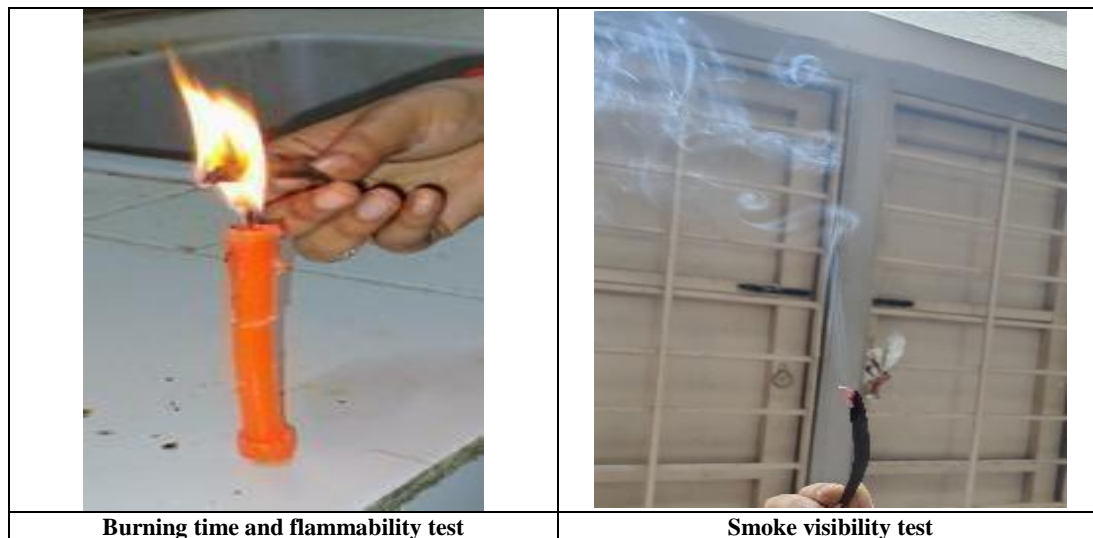


Fig 4: Evaluation Tests

Results and Discussion

1. Physical Appearance

The physical appearance of all ten formulations (F1–F10) of mosquito repellent sticks was assessed based on parameters such as color, odor, size, shape, surface nature, and homogeneity. The results are shown in Table 2.

All formulations exhibited a uniform rod shape with a standard size of 10 cm. The sticks were smooth in surface texture and showed homogeneous mixing of ingredients, indicating proper blending and compatibility among the herbal powders and binders. The variation in color, ranging from green to black and brown, was attributed to the differing proportions of herbal ingredients like neem, tulasi, clove, and sweet flag. All formulations had characteristic herbal odors, enhancing their acceptability as natural repellents.

2. Moisture Content

The moisture content ranged between 0.5% and 2% for all formulations as shown in Table 3. This range is ideal for incense-type preparations, as higher moisture may affect the burning efficiency while too low moisture can lead to brittleness. Formulations F5 and F9 recorded the lowest moisture content (0.5%), while F1, F3, F6, and F7 exhibited the highest at 2%. The results confirm that all formulations maintained appropriate moisture levels for optimal storage stability and performance.

3. Irritability Test

The irritability test was conducted to evaluate any adverse effects such as skin, eye, or respiratory irritation upon burning. As shown in Table 3, no irritancy was reported for any of the formulations (F1–F10), indicating the safety of the herbal formulations for indoor use. These findings demonstrate that the sticks are non-toxic and user-friendly, which is a significant advantage over chemical-based repellents.

4. Suffocation Test

The suffocation test was also carried out to detect any discomfort due to dense smoke inhalation. As seen in Table 3, none of the sticks caused suffocative discomfort. This supports the suitability of the prepared herbal sticks for regular household use without the risk of respiratory distress.

5. Burning Time

Burning time is a critical parameter for repellent efficacy. The formulations exhibited a burning time ranging from 15 to 30 minutes as shown in Table 3. F1 and F6 burned the shortest at 15 minutes, whereas F5 had the longest duration of 30 minutes. These variations may be due to differences in binder concentration, herbal composition, and compactness. A longer burning time is generally desirable for sustained repellent action, and F4, F5, F9, and F10 performed optimally in this regard.

6. Ash Content

Ash content provides insight into the amount of non-volatile matter remaining after combustion. It ranged from 0.21 g (F3) to 2.1 g (F9) as per Table 3. Lower ash values indicate efficient combustion, while higher ash suggests denser or inorganic content. F3 exhibited the least residue, indicating a more complete burn, whereas F9 showed the highest, likely due to higher quantities of mineral-rich components. These values are within acceptable limits for herbal incense products.

7. Smoke Visibility

Smoke visibility was assessed visually as shown in Table 3. High visibility was observed in formulations F1, F3, F7, and F8, which may contribute to enhanced mosquito repellency, as smoke acts as a deterrent. Formulations like F2, F5, F6, and F9 showed low visibility, possibly due to finer particle size or combustion rate. Although high smoke is beneficial

for repelling insects, it should be balanced to avoid user discomfort.

8. Mosquito Repellent Activity

The repellent activity was evaluated in mosquito-prone environments such as bedrooms, classrooms, and washrooms. In all test areas and time intervals, mosquitoes

were observed to escape after exposure to the smoke. There were no reports of irritation, coughing, tears, or headaches as shown in Table 3. These observations confirm the efficacy of the herbal repellent sticks in providing a non-toxic, environmentally friendly alternative to conventional mosquito repellents.

Table 2: Physical Appearance of Formulations (F1–F10)

| S. No. | Formulation | Colour | Odour | Size | Shape | Surface Nature | Homogeneity |
|--------|-------------|------------|----------------|-------|------------|----------------|-------------|
| 1 | F1 | Green | Characteristic | 10 cm | Rod-shaped | Smooth | Homogenous |
| 2 | F2 | Dark green | Characteristic | 10 cm | Rod-shaped | Smooth | Homogenous |
| 3 | F3 | Black | Characteristic | 10 cm | Rod-shaped | Smooth | Homogenous |
| 4 | F4 | Brown | Characteristic | 10 cm | Rod-shaped | Smooth | Homogenous |
| 5 | F5 | Black | Characteristic | 10 cm | Rod-shaped | Smooth | Homogenous |
| 6 | F6 | Green | Characteristic | 10 cm | Rod-shaped | Smooth | Homogenous |
| 7 | F7 | Dark green | Characteristic | 10 cm | Rod-shaped | Smooth | Homogenous |
| 8 | F8 | Black | Characteristic | 10 cm | Rod-shaped | Smooth | Homogenous |
| 9 | F9 | Brown | Characteristic | 10 cm | Rod-shaped | Smooth | Homogenous |
| 10 | F10 | Black | Characteristic | 10 cm | Rod-shaped | Smooth | Homogenous |

Table 3: Evaluation Parameters of Mosquito Repellent Stick Formulations (F1–F10)

| S. No. | Formulation | Moisture Content (%) | Irritability | Suffocation | Burning Time (min) | Ash Content (g) | Smoke Visibility | Repellent Activity |
|--------|-------------|----------------------|--------------|-------------|--------------------|-----------------|------------------|--------------------|
| 1 | F1 | 2.0 | NO | NO | 15 | 2.0 | High | Effective |
| 2 | F2 | 1.0 | NO | NO | 20 | 0.564 | Low | Effective |
| 3 | F3 | 2.0 | NO | NO | 23 | 0.21 | High | Effective |
| 4 | F4 | 1.0 | NO | NO | 28 | 1.2 | Average | Effective |
| 5 | F5 | 0.5 | NO | NO | 30 | 1.0 | Low | Effective |
| 6 | F6 | 2.0 | NO | NO | 15 | 0.93 | Low | Effective |
| 7 | F7 | 2.0 | NO | NO | 21 | 0.73 | High | Effective |
| 8 | F8 | 1.0 | NO | NO | 20 | 1.8 | High | Effective |
| 9 | F9 | 0.5 | NO | NO | 25 | 2.1 | Low | Effective |
| 10 | F10 | 1.0 | NO | NO | 23 | 1.5 | Average | Effective |

*NO – Not observed

Conclusion

The present study demonstrates the successful formulation and evaluation of herbal mosquito repellent sticks using powdered forms of *Azadirachta indica* (Neem), *Ocimum sanctum* (Tulasi), *Acorus calamus* (Sweet Flag), *Syzygium aromaticum* (Clove), and *Cinnamomum verum* (Cinnamon). All formulations exhibited acceptable physical characteristics, optimal moisture content, safe combustion profiles, and significant mosquito repellent activity in indoor environments. The absence of irritability and suffocation, combined with effective burning time and adequate smoke visibility, supports their safety and efficacy for practical use. These findings highlight the potential of plant-based repellents as sustainable, non-toxic alternatives to conventional chemical repellents. Given the rising concerns over synthetic repellent toxicity and resistance, such herbal sticks provide a viable strategy for integrated vector control. Their ease of use, biodegradability, and favorable safety profile make them suitable for domestic use in mosquito-prone regions. Future studies involving larger-scale field evaluations, standardization of active phytoconstituent concentrations, and comparative trials with commercial repellents are recommended to validate and optimize their long-term efficacy. Overall, this research contributes to the development of eco-friendly entomological interventions aimed at reducing mosquito-human contact and vector-borne disease transmission.

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