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Herbal mosquito repellent formulation using bioactive plant extracts and essential oils: An experimental study

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Abstract
The planet is full of mosquitoes. There are numerous mosquito repellents available on the market to combat them. However, the mosquitoes developed a resistance to them. In addition, consumers are experiencing numerous recognized and unknown negative consequences from them. In order to give dependable, long-lasting, and total protection from mosquito bites by killing them, an attempt has been made to develop a polyherbal insect repellent based on traditional methods and species found in kitchens and gardens. The repellents' effectiveness was assessed. The designed repellents were shown to be more effective, less expensive, and non-toxic than the chemical-based mosquito repellents now on the market. Chemicals produced by natural plants help them fend off phytogenic attacks. Mosquito with a variety of routes, including development controllers, metabolites, repellents, and protective feeding. These days, there is a need for natural mosquito repellents that are affordable, dependable, non-toxic, safe for the environment, and biodegradable.

Keywords: Mosquito repellent, essential oils

Introduction

Yellow fever, dengue hemorrhagic fever, encephalitis, pandemic polyarthritis, and malaria are among the mosquito-borne illnesses that continue to be a significant global health problem. Malaria is the most serious of these; according to the World Health Organization, it kills about 3 million people annually [1, 2]. With the exception of Antarctica and a few places like France, mosquitoes are found practically everywhere in the world. Approximately one out of every seventeen fatalities worldwide are caused by them, and they infect over 700 million people with diseases each year [3, 4].

Male mosquitoes mostly eat nectar from flowers, but female mosquitoes require a blood meal from humans or animals to develop their eggs [5].

Sleep can be disrupted by the characteristic high-pitched buzz that mosquitoes produce when in flight. Both saliva and anticoagulants are injected by female mosquitoes [7].

Within minutes of a mosquito bite, the body's immune system produces antibodies that cause redness and itching. Some people may experience a more severe reaction that results in blisters, bruises, or severe inflammation [8].

The primary reason of mosquito bites' noticeable and bothersome symptoms is an immunological reaction, more precisely hypersensitivity. Immunoglobins antibodies produced in response to antigens found in mosquito saliva cause this reaction. Effective insect repellents are desperately needed since mosquito-borne diseases have a substantial negative impact on health, including morbidity and mortality [9].

There are numerous chemical and non-chemical mosquito repellent products on the market. Our goal in this study was to find natural repellents that can offer reliable, long-lasting defense against mosquito bites. We created A herbal mosquito repellent using readily available garden and kitchen herbs based on traditional knowledge, takinginto account the drawbacks and possible adverse effects of synthetic repellents. By either killing or repelling mosquitoes, this composition is intended to provide safe, economical, and effective protection. The created herbal solution is less hazardous and more environmentally friendly than chemical-based repellents that contain potentially harmful substances like permethrin, DEET (N,Ndiethyl-meta-toluamide), and malathion [10, 11].

A wide range of chemical and alternative mosquito repellent products are available in the market. In this study, we aimed to identify natural repellents that can provide effective and long-lasting protection against mosquito bites. Considering the limitations and potential side effects of synthetic repellents, we developed a herbal mosquito repellent using commonly available garden and kitchen plants based on traditional knowledge. This formulation is designed to offer safe, cost-effective, and efficient protection by repelling or killing mosquitoes. Compared to chemical-based repellents containing compounds such as allethrin and prallethrin, which may have harmful effects, the developed herbal product is less toxic and more environmentally friendly A wide range of chemical and alternative mosquito repellent products are available in the market. In this study, we aimed to identify natural repellents that can provide effective and long-lasting protection against mosquito bites. Considering the limitations and potential side effects of synthetic repellents, we developed A herbal mosquito repellent using commonly available garden and kitchen plants based on traditional knowledge. This formulation is designed to offer safe, cost-effective, and efficient protection by repelling or killing mosquitoes. Compared to chemical-based repellents containing compounds such as allethrin and prallethrin, which may have harmful effects, the developed herbal product is less toxic and more environmentally friendlyInsect repellents are an alternative to the use of insecticides.

They may be applied to the skin to protect an individual from the bites of mosquitoes, mites, ticks and lice or, less commonly, may be used to exclude insects from an area, such as in packaging to prevent infestation of stored products Insect repellents are an alternative to the use of insecticides.

What is a mosquito repellent?

A material that is applied to skin, clothing, or other surfaces to prevent mosquitoes from settling there is known as a mosquito repellent. In order to lessen human-mosquito contact, the chemical is manufactured in a way that renders the surface unpleasant and undesirable to mosquitoes. Insects are repelled but not killed by mosquito repellents. As a result, they are neither pesticides nor insecticides. They aid in the prevention and management of mosquito-borne illness outbreaks, including Japanese encephalitis, dengue fever, malaria, and yellow fever [12].

By obstructing mosquitoes' ability to detect the carbon dioxide and lactic acid created when humans perspire, their active ingredient serves as the only means of repelling mosquitoes. Additionally, these products have additional chemicals that help with cosmetic finishing [13].

Mosquito repellent mode of action?

It has been discovered that a variety of physiological or biochemical processes can lead to behavior that might be classified as repellent. DEET is believed to repel mosquitoes by blocking lactic acid receptors, which prevents them from flying upwind and causes them to "lose" their host. Studies looking at mosquito physiology after a blood meal provide more proof that lactic acid plays a part in host seeking. After consuming blood, *Aedes aegypti* ceases its host-seeking behavior. Lactic acid-sensitive neurons' sensitivity has been shown to decrease after a blood meal, and this decrease coincides with the end of host-seeking activity. After oviposition, lactic acid sensitivity returns to normal [14].

Mosquito repellents of natural origin

Certain insect repellent compositions, contain natural substances. Citronella is a common plant component in mosquito repellent products in the United States. This oil's insecticidal qualities were identified in 1901, and for a while it was applied to hair to keep lice and fleas at bay. Contrary to popular belief, incense or citronella candles did not lessen mosquito biting pressure. When combined with 2% coconut oil, neem oil from *Azadirachta indica* offered 12 hours of total protection against Anopheles mosquitoes [6].

Classification of Mosquito Repellents:

The following categories can be used to broadly classify the insect repellents currently on the market: (Figure1)

- **Physical methods of Mosquito Repellents**

Physical insect repellent techniques serve as a barrier to prevent mosquito bites. Emptying stagnant water into rain gutters, old tires, buckets, plastic covers, etc. are examples of physical mosquito deterrent activities. In order to prevent mosquitoes from finding the ideal location to lay their eggs, it is highly desired to change the water in bird baths, fountains, pools, rain barrels, etc. at least once a week. Additionally, wearing long-sleeved clothing is advised, particularly during dawn and twilight. To further keep mosquitoes out of the house, windows and door screens need to be fixed. Mosquito nets, coils, and other commercially available repellents fall under this category. When it comes to safety, mosquito netting is thought to be superior to coils and other repellents, especially when sleeping. These nets act as a protective barrier to prevent mosquitoes and other insects from attacking people [12].

- **Mechanical methods of Mosquito Repellents**

Yellow light was discovered to draw fewer insects than white light, and this feature may be applied to a mechanical mosquito repellant. The Electric Mosquito Zapper, mosquito magnets, and other techniques are examples of mechanical insect repellents. An electric mosquito zapper works by trapping mosquitoes with ultraviolet light and killing them when they come into touch with its deadly electric charge dose [13].

- **Chemical methods of Mosquito Repellents**

Measles, Lyme disease, dengue fever, bubonic plague, West Nile fever, and other insect-borne diseases can be prevented and controlled with the use of chemical repellents, which are the most effective personal insect-seeking defense [15].

This can be further classified into two groups, based on the source of the chemical repellents:

- **Natural Mosquito Repellents**

At the human and community levels, natural resources with shown insecticidal or repellant properties have been crucial in halting the spread of vector-borne diseases. Since the beginning of human civilization, humans and mosquitoes have coexisted together, and we have employed natural resources to protect ourselves against mosquito bites and vector-borne illnesses. Since ancient times, these herbal mosquito repellents have been created and marketed, which has resulted in the development of personal protection techniques [15].

- **Synthetic Mosquito Repellents**

Although chemicals derived from plants have been used for a long time as mosquito repellents, they nevertheless have some drawbacks. By contrast, the effectiveness of these herbal repellents seems to wear off more quickly. As a result, these substances require frequent reapplication and only provide temporary protection. Heavy odor, skin irritation, and potential health hazards due to infrequent toxicity testing are some disadvantages. Due to the drawbacks of using natural plant resources as mosquito repellents, such as their short repellence period and expensive cost, synthetic repellents have taken the place of natural ones [15].

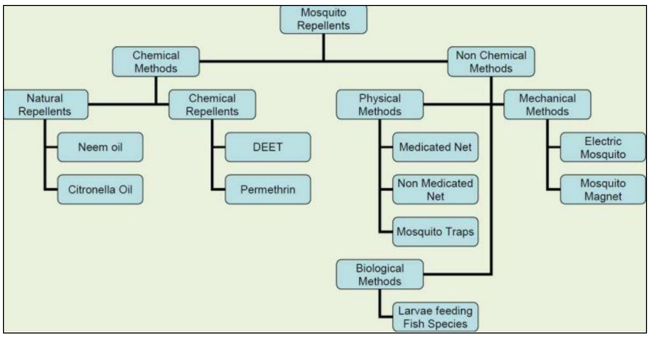

Fig 1: Classification of Mosquito Repellents

The foundation of both conventional and contemporary medicines, medicinal plants are a significant source of bioactive chemicals that aid in the treatment of illness and enhance general health. Researchers have thoroughly investigated plant-derived compounds for a variety of therapeutic purposes since they contain such valuable ingredients. According to the results, a topical mosquito repellent cream with 1% curcumin and 1.5% embelin is stable, safe, and effective [16].

Since mosquitoes are found all throughout the world, a variety of repellents have been created to keep them under control. However, several of these products have become resistant to mosquitoes, and their use has been linked to a number of known and unknown negative effects in people. As a result, an effort was made to create a polyherbal mosquito repellent using plant elements that are frequently found in gardens and kitchens as well as traditional knowledge [17].

Plant Profile

1. Neem Leaves

Fig 1: Neem Leaves

In tropical and subtropical parts of the world, neem trees (*Azadirachta indica*), which are members of the Meliaceae family, are widely recognized. Nimbin, nimbidin, and nimbolides are only a few of the many physiologically active substances found in neem seeds. Azadirachtin, which is found in the seeds at a concentration of roughly 5 mg/g of the kernel, is the most powerful of them. Extracts from neem seeds have shown a variety of insecticidal effects on a wide variety of insect species. Insect growth regulation, ovicidal action, fecundity suppression, prevention of metamorphosis and disruption of development and reproduction, repellence and anti-feeding, and deterrent of egg-laying are some examples. The oil that is derived from neem seeds is its primary product. Additionally, neem seed extracts can kill the larvae of diseases that are important to public health, including yellow fever, dengue, malaria, filaria, and dengue hemorrhagic fever. Neem seed extract may be used as a bio-insecticide in addition to conventional malaria prevention strategies [18, 19]. It regulates growth naturally. It produces an environment in a vaporizer that interferes with the mosquito's sensory receptors, making it harder for them to "smell" or find human prey. The insect may potentially die from prolonged exposure in an enclosed space.

2. Garlic

Fig. 2: *Allium sativum* L. (garlic)

Garlic, or *Allium sativum* L., is a wonderful spice and a common treatment for a number of illnesses and conditions. It belongs to the Alliaceae family. Garlic is grown almost everywhere in the world, and it seems to have started in central Asia before spreading to other regions. Garlic's exceptional biological effects, such as its antioxidant, cardiovascular protective, anticancer, anti-inflammatory, immunomodulatory, anti-diabetic, anti-obesity, and antibacterial qualities, have been the subject of several research in recent decades. At least 33 sulfur compounds, a number of enzymes, 17 amino acids, and minerals like selenium are found in garlic. Compared to other Allium species, it has a greater concentration of sulfur compounds. Garlic's strong smell and many of its therapeutic benefits are caused by sulfur molecules. Garlic does not contain allicin (diallylthiosulfinate or diallyl disulfide), one of the most physiologically active substances, unless it is crushed or sliced; damage to the garlic bulb triggers the enzyme alliinase, which converts alliin to allicin. Sulfur is extremely repulsive to mosquitoes. These volatile sulfur compounds spread quickly when garlic is cooked. It serves as a "keep away" signal, keeping mosquitoes out of the room altogether [19].

3. Lemon grass oil

Fig 3: Lemon grass and oil

According to studies, lemongrass (*Cymbopogon citratus*) essential oil has a 90% to 100% repellency rate against mosquitoes. Citral and geraniol, two of its main active ingredients, repel target species and obstruct their capacity to recognize human attractants. It functions as a synergist and scent mask. The peel's oil sacs contain limonene, a naturally occurring pesticide. Its main function in your recipe is to cover up the strong "garlic" odor, making the air more palatable for people while also acting as a secondary barrier [20].

4. Cinnamon Oil (*Cinnamomum cassia*)

Growing in Sri Lanka and East and Middle Asia, cinnamon is a tropical tree belonging to the Lauraceae family. Cinnamaldehyde, cinnamic acid, cinnamate, cinnamyl acetate, trans-cin-namaldehyde, and eugenol are among the many bioactive phytochemicals found in cinnamon extract. Cinnamon essential oils have been shown in numerous studies to have larvicidal, ovicidal, adulticidal, and repellant properties against mosquitoes. It is among the most potent natural insecticides. Garlic by itself cannot provide the "knockdown" action in an electric heater, which paralyzes or kills the mosquito [21, 22].

Material and Methods

Procurement and identification

Collection of plant material from the plants such as Garlic bulb, Neem leaves from the local market get authenticated by Botany department of Jijamata Science college, Nandurbar. Essential oils of Lemon grass oil, Cinnamon oil, Castor oil, Ethanol were procured from Sahyadri Scientific Suppliers, Satara. India. Every chemical and solvent utilized was of analytical quality.

Preparation of Herbal Mosquito and Mosquito repellent Vaporizer

The formulation criteria for a 50 ml electric liquid vaporizer (the type used with a heating machine) differ from those for a topical spray. The mixture must be thin enough to move up the graphite or porous wick yet stable enough to avoid burning because the machine employs a ceramic heater to evaporate the liquid [16, 17].

Table 1: Composition of Mosquito repellent Vaporizer

Sr. No	Ingredients	Role of ingredient	Quantity	Percentage
1	Neem Leaf Extract	Primary Insecticide	10 ml	20%
2	Garlic Bulb Extract	Strong Repellent	5 ml	10%
3	Lemon Grass oil	Scent Masking	5 ml	10%
4	Cinnamon Oil	Active Volatile (Larvicidal)	2.5 ml	5%
5	Castor Oil Fixative	(Slows evaporation)	2.5 ml	5%
9	Ethanol (95%)	Solvent/Solubilizer	15 ml	30%
7	Distilled Water	Diluents	10	20%

Step 1: Preparation of the Extracts [19]

1. **Maceration:** Crush the neem leaves and garlic.

2. **Soak:** In a sealed container, soak the crushed components in 15 ml of ethanol for a whole day. When it comes to extracting active alkaloids, such as Azadirachtin from neem, ethanol works better than water.

3. **Ultra-Filtration:** Pass the mixture through multiple layers of muslin cloth or a very fine coffee filter. The final liquid ought to be completely transparent.

Fig. 4: Neem Residue

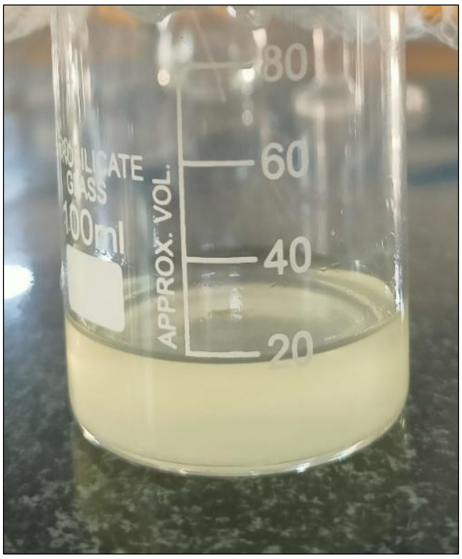

Fig. 5: Garlic Residue

Step 2: The Oil-Water Coupling [23, 24]

1. Mix the Cinnamon Oil, Castor Oil and Lemon Grass Oil into the Ethanol extract first. Ethanol acts as a bridge (coupling agent) between the oils and the water.
2. Slowly add the Distilled Water to the mixture while stirring constantly.
3. The solution may turn slightly cloudy (the Tyndall effect); this is normal for herbal emulsions.

Evaluation of Formulated Mosquito Repellent Liquid [17]

- **Odor Profile (Olfactory)**

Initial Note (Top): Citrusy, sharp, and medicinal. The ethanol and lemon peel reach the nose first, giving it a fresh, somewhat "hospital-like" smell.

Heart Note (Middle): Spicy and warm. This stage is dominated by the cinnamon oil. A potent "masking agent," cinnamon is chemically engineered to encircle the heavier garlic molecules and make them more palatable.

Base Note (Dry-down): Nutty, earthy, and a little strong. The garlic and neem live here. You'll note a persistent "savory" or "sulfuric" undertone that is typical of natural repellents while the cinnamon tempers the garlic.

- **Visual & Physical Properties (Organoleptic)**

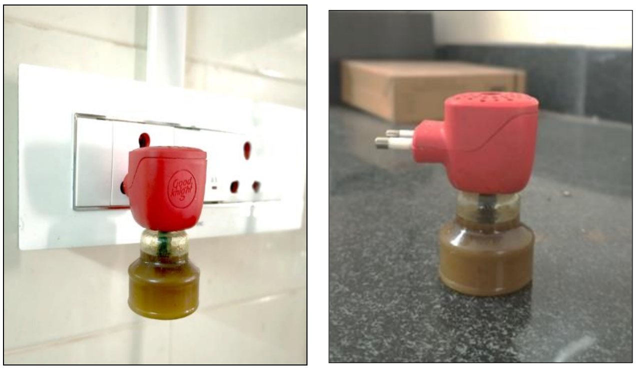

Fig 6: Herbal Mosquito and Mosquito repellent Vaporizer

Properties	Description
Colour	Golden-Green to Pale Amber: The Neem leaves provide chlorophyll (green), while the Cinnamon and Castor oils add a golden/amber hue.
Clarity	Translucent to Slightly Turbid: Because it is an oil-in-water/alcohol mixture without synthetic emulsifiers, it may look slightly "milky" or cloudy (the Tyndall effect).
Texture	Oily-Fluid: It should feel thinner than pure cooking oil but thicker than water. It will have a "slip" or "greasiness" due to the Castor oil.
Consistency	Non-viscous: For an electric heater, it must remain "runny." If it looks like syrup, it will fail to climb the wick.

- **Sensory Evaluation Checklist** [25,26]

a. The Blotter Test

- Drop 2 drops on a piece of paper
- After 1 hour, smell it. If you only smell garlic, the cinnamon concentration is too low.

b. The Transparency Test:

- Hold the 50ml bottle against a 60W light bulb
- You should see a clear "glow" through the liquid
- If it looks "muddy" or has floating black specs, your filtration was insufficient.

c. The Skin Feel (Optional)

- Rub a drop between your thumb and forefinger
- It should feel smooth (Castor oil) and then slightly cool as the Ethanol evaporates. It should not feel "gritty."

Discussion and conclusion

It was determined that the polyherbal repellent is more effective, less expensive, and non-toxic than the chemical-based repellents now on the market, and it keeps people healthy and mosquito-free. This work successfully developed a natural basis mosquito repellent. The liquid including plant extract and essential oil was assessed and shown to have repelling qualities. To determine the mean percentage, the test is run three times. It was discovered that the mean was 40%, which is more than half. Thus, it demonstrates how excellent the formulation is. There have been no known negative effects. As a result, the product is completely safe. Additionally, the formulation was cost-effective and environmentally friendly.

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