Chapter 15

Use of Essential Oil against Mosquitoes

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ABSTRACT

Diseases spread by mosquitoes are thought to be the cause of one million fatalities worldwide each year. To prevent certain diseases, the environment must be improved (e.g., reduced stagnant water) and managing adult and juvenile mosquito populations. A couple of the main drawbacks of utilizing chemical insecticides are environmental contamination and mosquito resistance. Essential oils are fascinating and potent natural plant products that have been utilized medicinally since ancient times. Essential oils (EOs) have a variety of effects on mosquitoes, such as repellant, ovicidal, larvicidal, pupicidal, and adulticidal effects. EOs are mostly utilized as sources of active ingredients for different repellents when it comes to their ability to combat mosquitoes.

Because of their strong breakdown in the environment little adverse effects on non-target animals and selective action on target. Recently, pesticides based on EO have been presented as artificial insecticide substitutes to keep mosquitoes away. Several investigations about using EOs to repel insects are found in the literature. In this chapter, we summarize the role of EOs in controlling the mosquito population.

KEYWORDS		
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INTRODUCTION

Many people across the world suffer from parasites and parasitic diseases, which provide a variety of difficulties in terms of treatment and management. (Alvi et al., 2020; Alvi et al., 2021; Alvi et al., 2022; Alvi et al., 2023). Among parasites the most significant arthropods for public health are mosquitoes (Sanei-Dehkordi et al., 2018). In addition to encephalitis, dengue, yellow fever, *chikungunya*, malaria, and *filariasis,* they could spread numerous other illnesses. The most significant mosquito-borne illness is malaria; 405,000 deaths and 228 million cases were recorded globally in 2018 alone (Kurtovic et al., 2020). Approximately 400 million dengue infections occur each year, with about 25% of those individuals exhibiting clinical symptoms. Approximately half of the world's population is susceptible to dengue infection (Duarte et al., 2020).

Larval control is a crucial component of the integrated management of most mosquito species (*Diptera culicidae*) and has been achieved by using various pesticides. Disease-endemic nations have a significant financial burden from vector-borne illnesses such as *malaria, dengue fever*, and *filariasis*, which cause widespread morbidity and mortality (Almeida et al., 2020).

In poor nations where epidemics of vector-borne diseases are occurring, mosquito management is a major problem. Chemical insecticides, or synthetic pesticides, are often used to control mosquitoes in their adult and immature stages (egg, larva, and pupa). Side effects on non-target populations (particularly people), negative environmental consequences contaminating water, soil, and air have been observed by the use of these insecticides. The emergence of resistance significantly increased in recent years (Esmaili et al., 2021).

In developing nations, the *organophosphate temephos* is still commonly employed however in Europe and the USA; microbial insecticides are used to control larvae. The European Community has been strictly reviewing all chemical larvicides due to their harmful effects on *aquatic biocoenosis*. This has resulted in the withdrawal of *temephos* in Europe. Essential oils (EOs) are becoming more popular as low-risk pesticides in the past few decades. In addition to effectiveness, the majority of research reported that EOs had no negative effects on the environment or on human health (Masetti, 2016a, 2016b).

One method of controlling the adult insects from emerging and becoming the pathogen's active "transporter" or vector—which can be harmful—is to target the insect vector during its formative stages. This strategy has been proposed as critical for controlling dengue vectors and halting the spread of disease viruses. In areas where it is widespread, malaria in particular still poses a serious health risk to newborns and early children. A total of 90% of malaria-related mortality occurs in newborns and young children, with the majority occurring in sub-Saharan Africa. Every year, there are 350–500 million cases of malaria worldwide, and at least one million people die from the disease (WHO, 2009).

Dengue fever is also one of the most significant viral infections spread by mosquitoes worldwide. The incidence has tripled in the past 50 years. Over 100 endemic nations and regions where dengue viruses can spread to around 2.5 billion individuals. Every year, there are up to 500,000 infections, 50 million episodes of hemorrhagic illness caused by dengue, and 22,000 fatalities—mostly in children—from the virus (WHO, 2012).

What are Essential Oils?

The majority of Essential oils are colorless or pale yellow, liquid, or have a lower density than water. They are hydrophobic and soluble in alcohol, non-polar or weakly polar solvents, waxes, and oils, but only slightly soluble in water. Highly concentrated substances called essential oils (EOs) are taken from barks, fruit rinds, stems, flowers, seeds, roots, and resins (Fatimah, 2016). Essential oils are complex combinations of volatile molecules that are created by living things and can only be physically extracted from a whole plant or a plant portion that has a recognized taxonomic origin (pressing and distillation) and are used as health protection against many vectors (Moghaddam and Mehdizadeh, 2017).

Because of their flavor, odor, and therapeutic qualities, EOs are frequently used in a wide range of goods, including meals, medications, and cosmetics. One of the most labor-intensive and time-consuming procedures is extracting essential oils (Hanif et al., 2019)

Numerous studies have been published that extract Essential oils (EOs) from a broad range of plant species and reported that whole extract or some of its purified constituents have insecticidal action on mosquito larvae (Almadiy, 2020). EOs are extracted from plants using techniques like distillation or other extraction processes. Generally speaking, the primary components of EOs are *terpenoids* and, to a lesser extent, *phenylpropanoids* (Hou et al., 2022).

Essential oils, also known as oily liquids, are often obtained by hydrodistillation from different portions of plants such as the stem, flower, bark, and rhizome, with an apparatus similar to the Clevenger. There are a lot of studies on using essential oils to repel insects in the literature. However, because some of their constituents are volatile, the uses of essential oils as insecticides and repellents are restricted (Khanavi et al., 2013). The biological actions they possess are diverse and include repellant, larvicidal, leishmanicidal, and antibacterial properties. Because of their high environmental degradation rate, selective action on target, and low adverse effects on non-target animals, EO-based insecticides have recently been proposed as synthetic options for controlling mosquito populations (Esmaili et al., 2021).

Essential Oils as Biocides

Plant products have been employed as insecticides since the Roman era; when species like black hellebore (*Veratrum nigrum*) and white hellebore (*Veratrum album*) were used. A variety of plant pathogenic microorganisms, including (*Fusarium oxysporum, Alternaria alternative, Penicilium italicum, Penicilium digitatum,* and *Botyritus cinerea*), were investigated for their antibacterial properties using essential oils of fennel, peppermint, caraway, eucalyptus, geranium, and lemon. Because the essential oils of fennel, peppermint, and caraway were effective at suppressing the microorganisms under test, they were chosen as the active ingredients in the biocide composition. With the use of several fixed oils (sesame, olive, cotton, and soybean oils) and emulsifiers (Emulgator B.L.M. Tween20 and Tween80), successful emulsifiable concentrates (biocides) were produced from these oils (Abo-El Seoud et al., 2005).

Larvicidal Activity

Application of essential oils (*Cedarwood, clove, peppermint, thyme*, and *Bourbon geranium*) in various combinations and concentrations (5, 10, 25, 50, 75, and 100%) on human skin proved to be repellent against *Anopheles albimanus, Wiedemann* and *Aedes aegypti*. The only thing that kept *Ae. aegypti* away were large doses of peppermint oil. With a protection duration ranging from 1½ to 3½ hours, clove oil and thyme proved to be the most efficacious insect repellents. For one to two and a half hours, *An. albimanus* biting was inhibited by combining 50% *clove oil* with 50% *geranium* oil or 50% *thyme oil*. Skin irritation is a potential side effect *of clove, thyme*, and *peppermint* oils. Many plant oils, including those from thymus, basil, cinnamon, and citronella, show promising results as larvicides for mosquitoes (Barnard, 1999).

Organophosphorus chemicals, such as *temephos, fenthion,* and *chlorpyrifos*, are the most widely used larvicides because of their high activity level against aquatic insects and mosquito larvae. Because *organophosphate* larvicide is less hazardous to mammals, humans, fish, and birds, it is advised as the best larvicide for controlling *Aedes* and *Anopheles*. Many plant oils, including those from *thymus*, *basil, cinnamon*, and *citronella*, show promise as larvicides for mosquitoes. Examining larvicides made from plant oils used to repel mosquitoes, is the main focus of a previous study (Pitasawat et al., 2007).

Essential oils are considered harmless plant materials; therefore, it seems safe to utilize them as botanical larvicides. When EOs are added to water in a controlled laboratory condition, mosquito larvae exhibit acute toxic effects. Compared to LC_{50} values for chemical or microbiological larvicides, the median lethal concentrations (LC_{50}) of essential oils are higher. Few EOs have LC_{50} values less than 1 ppm, and according to multiple published studies, more than 50 ppm were needed to kill 50% of the larvae that were evaluated Numerous writers have demonstrated how the time of year, a plant's age, its history of disease or insect infestation, its geographic location, agronomic methods, and climate stressors all affect the concentration of essential oils in plants (Dias and Moraes, 2014).

In recent scientific literature, interest has significantly increased in the insecticidal action of essential oils on mosquito larvae. The effectiveness of the EOs that have been reported thus far, however, cannot be compared to that of chemical or microbiological larvicides. Furthermore, a majority of EOs' low mammalian toxicity and absence of environmental effects have been stated. The majority of aromatic plants in developed countries, where there is an opportunity to fully utilize their potential as botanical larvicides (Masetti, 2016b). For a long time, several popular EOs and their primary ingredients have been employed as food and beverage additives, cosmetic perfumes, and pharmaceutical goods. For mammals and other animals, these EOs exhibit minimal oral toxicity. The shortest environmental half-lives of Essential oils (EOs) make them more environmentally friendly than conventional synthetic insecticides (Assadpour et al., 2023).

Essential Oil as Adulticides

The adult female mosquito, which bites and spreads fatal viruses or other infections, is the target of most control plans. Typically, adulticides are used as surface treatments that are applied as residue. Several compounds found in EOs have been shown to have adulticidal properties; these chemicals come from plants belonging to the *Lamiaceae, Miliaceae, Rutaceae*, and *Ingeberaceae* families (Chellappandian et al., 2018). The Essential oil derived from *L. camara* leaves exhibits adulticidal efficacy against various mosquito species, making it a potential ingredient for use in oil-based insecticides (Dua et al., 2010).

EOs Inhibiting the Suction Activity of Mosquitoes

Using repellents to stop insects from sucking blood is the basis of protection. Natural repellents, like aromatic oils, work by discouraging females from sucking blood and hence from spreading infections. Though popular and reasonably effective, this indirect protection technique frequently has reduced efficacy because of the requirement to reapply repellent at regular intervals of many hours. In lab testing, it was shown that applying various amounts and combinations of the following five essential oils on human skin: *clove, peppermint, thyme, cedarwood*, and *Bourbon geranium* effectively repels mosquitoes. The best oils for keeping mosquitoes away were *thyme* and *clove,* which, depending on the dosage of the oil, protect for 1½ to 3½ hours (Barnard, 1999).

Nano Formulations and Essential Oils or Control of Mosquitoes

Mosquito control using EO-based Nano formulations also has been implemented. High- and low-energy techniques are typically utilized to create Nanoemulsions. High-energy techniques include ultrasonic, high-pressure homogenizer, and microfluidizer-assisted fabrications. Temperature of phase inversion, composition of phase inversion, diffusion of solvent, and spontaneous- emulsification are examples of low-energy processes. When creating EO-based Nanoemulsions, spontaneous emulsification is favored over alternative methods. Using this method, oil, water, and surfactant optimization is used to create Nanoemulsions. Thus, physical and chemical stress like temperature and pH do not affect the generated Nanoemulsions in this way (Esmaili et al., 2021).

***Cymbopogan citratus Stapf* (*Graminae*) Essential oil's Anti-Filarial Mosquito Activities**

Herbal products are frequently utilized because of their strong antibacterial, aromatic, and therapeutic qualities. By adjusting the release rate, essential oils and scents can be applied as micro- or nano-capsules to textile substrates to extend their lifespan. The ovicidal, larvicidal and repellant properties of essential oils obtained from *Cymbopogan citratus* through steam distillation were assessed about the filarial mosquito *Culex quinquefasciatus*. A 24-hour treatment period was used to observe the larval mortality. The larval instars two, three, and four were found to have LC50 values of 144.54 ± 2.3, 165.70 ± 1.2, and 184.18 ± 0.8 ppm, respectively. At 300 ppm, there was 100 percent ovicidal activity seen .*C. citratus* doses of 1.0, 2.5, and 5.0 mg/cm2 offered 100% protection for three, four, and five hours, respectively, in a skin-repellent test. For a 12-hour period, this Essential oil's overall protection percentage was 62.19% at 2.5 mg/cm2, 74.03% at 5.0 mg/cm2, and 49.64% at 1.0 mg/cm2 (Ghayempour and Montazer, 2016).

***Citronella* Essential Oil**

Citronella oil is an extensively researched Essential oil that is mostly derived from *Cymbopogon nardus*. The effectiveness of this vital oil against mosquitoes has been demonstrated. In addition to having a mosquito-repelling effect, it is a combination of ingredients with *citronellol, citronellal*, and *geraniol* as primary elements contributing to numerous actions such as antitrypanosomal, anthelmintic, antimicrobial, antioxidant, anticonvulsant, and wound healing. Because of its great performance, low toxicity, and satisfied customers, *Citronella* Essential oil is listed as a repellant for insects by the US Environmental Protection Agency (EPA). However, its practical applications are limited by its low stability in the air and high temperature. (Sharma et al., 2019).

***Hazomalania voyronii* Essential Oils as Insecticidal and Mosquito Repellent**

In Madagascar, the traditional practice of using *Hazomalania voyronii*, also referred to as Hazomalana, to ward against bug bites and repel mosquitoes is passed down through the generations. We examined the cytotoxicity of three important insect species for agriculture and public health ,*Musca domestica, Culex quinquefasciatus* and *Spodoptera littoralis* and also the effectiveness of the Essential oils (EOs) derived from the wood, fresh or dry bark ,stem of *H. voyronii* to keep away major mosquito vectors, *Aedes aegypti* and *Culex quinquefasciatus* (Benelli et al., 2017).

Clove Oil and Cinnamon Oil

The long-lasting protection ticks and mosquito bites were offered by lotion emulsions containing 10% v/v clove or cinnamon oil. We conclude that combining active chemicals from the EPA Minimum Risk Pesticides list into a 10% v/v emulsion can provide complete protection against tick crossings and mosquito bites for almost an hour (Luker et al., 2023).

Repellency Effect against Ades albopictus

There was need to develop environment-friendly and novel mosquito larvicides. Six Essential oils—*Asteraceae, Rutaceae, Mentha piperta, Carvacryl, Citronella*, and *Eucalyptus*—were evaluated in a lab setting to determine how effective they were at repelling *Aedes albopictus* mosquitoes. Human subjects were only used in the testing of Citronella and Eucalyptus oils. Mice were 100% protected after 7 hours with 7% *carvacryl* oil. Humans were protected with 15% *Eucalyptus* oil for at least three hours; five hours of protection was achieved by adding 5% vanillin.

***Thymus vulgaris* Essential oil Nano Emulsion**

After 24 hours of exposure, the thyme oil Nano emulsion's maximum activity against *C. tritaeniorhynchus* was detected, and after 24 hours of exposure, its chitosan encapsulation was most efficient against *A. stephensi*. It was possible to see consistent morphological changes in the larvae of many mosquito species. Therefore, additional research on these Nano emulsions and encapsulations for use against other insect pests in agriculture may be necessary.

Conclusion

Natural compounds made from vegetable matrices, such as Essential oils (EOs), have a large range of secondary metabolites that can act against multiple biological systems, making them potentially considered environmentally acceptable pesticides. The application of some EOs to establish green methods for cultural heritage protection has been assessed by conservation scientists in light of these features. To control dengue mosquito vectors, local, regional, and rural communities with few alternatives continue to be interested in using plant extracts, chemicals, or their derivatives as inexpensive, safe phytochemical insecticides. Since plant-based medications are widely accessible, inexpensive, and seldom cause negative effects, their application in the preservation of cultural assets can undoubtedly improve both environmental and human health when used in accordance with contemporary restoration protocols.

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