Review of Herbal mosquito repellent

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***Abstract*: Mosquito is a deadliest pest known to man. Prevention of mosquito bites is one of the best intervention methods to reduce disease. Various mosquito repellents are used in day to day lives which are synthetic and continue use of these repellents can cause health hazards and environment hazards. From ancient times various plants are used in form of repellents, fumigants and insecticidal agents. Most of the plants contain phytochemicals which they use as repellent in preventing attacks from various insects. The current paper summarizes research aimed at developing safe and effective herbal insect repellent compositions. In ancient times orange seeds and peel powder were used as insecticide. The dried peels of most citrus fruits have been used in various ways in controlling pest. Orange oil extracted from peels of orange can be used as repellent. It consists majorly Limonene a monoterpene which gives orange oil a peculiar odor and taste which shows repellent properties. Linalool which has perfumery property also shows repellent properties against insects which is widely used as flavoring agent and in production of perfumes. It has been also used in both topical preparations and combustible products as. It can be used instead of synthetic repellent as it has beneficial uses for humans in concern of health and low risk of side effects. Our study aims at investigating the repellent activity of phytochemical extracts (orange oil) from orange peels.**

***Keywords*: Mosquito, Repellent, Herbal, Orange, Plant extract, Essential oil**

INTRODUCTION

Mosquito have been known to human for many decades and are little flies that transmit a variety of disease through there saliva (1). The majority if anopheles species are parasite carriers and cause disease and death. Several mosquito species from the genera Anopheles and Aedes serve as vectors for pathogens that cause diseases such as Dengue fever, Malaria, Yellow fever, Japanese Encephalitis, and other infections(2). Mosquitoes alone are responsible for the transmission of diseases to approximately 700 million people worldwide, with over one million deaths reported each year(3). Malaria is the major cause of death. According to the WHO child dies from malaria every 30 seconds and 300 to 500 million cases of malaria occurred each year (4).

The greatest way for preventing illness transmission to avoid mosquito bites. This is accomplished through the use of mosquito repellent such as lotion, cream, coils, sprays and other similar products. Synthetic mosquito repellent such as Allethrin, Prallethrin, dimethyl phthalate, DEET and other are new widely utilized (5). Herbal formulations, which are proven to be helpful against a wide range of diseases and ailments, are gradually gaining popularity around the world1. However, including a statement that plant cures are effective and have no side effects is a good idea. Many of the herbs and bushes have been discovered to have medicinal and therapeutic effects, as well as mosquito larvicidal and repellent capabilities. Because synthetic liniment has a negative impact on the environment and non-target creatures, plant-based insecticidal solutions have been tested as an alternative technique to control a variety of insect pests and vectors in the recent past(6). When the synthetic chemicals are used often, they can pose a number of health and environmental risk photochemicals found in many plants have phytophagous insect repellent characteristics. Phytophagous (plant-based) insects are protected by compounds found in the majority of plants. The category include repellent, feeding deterrents, poisons, and growth regulators among other things. Humans and stick domestic animals are not poisoned by plant based repellents and they are easily biodegradable (7). Natural items are safer for people when compare to artificial substances. As a result, the time has come to investigate ecologically friendly biological material for insect pest control. Different researchers have noticed that phytochemicals generated from plant resources can operate as larvicidal, insect development regulators, repellents, and oppositional attractants, with deterrent properties. In many parts of the world, plant products have long been used to repel or kill mosquitoes. The urgent need for phytochemicals to be investigated as insect repellents. So, our study estimated that various essential oils can be used as mosquito repellent due to their characteristic odour.

MOSQUITO REPELLENT

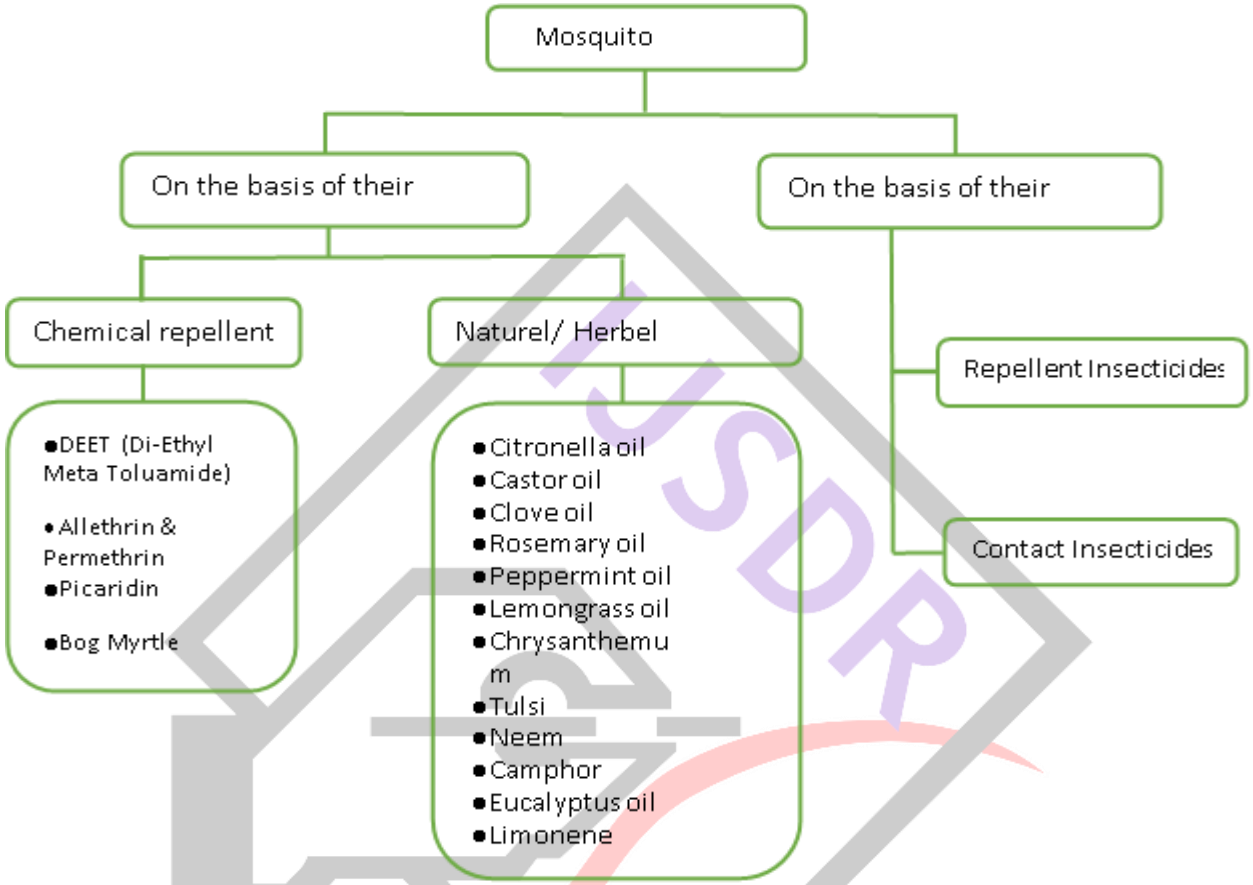
History

Insect repellent compounds have been employed to displace or kill insects since antiquity, when various plant oils, smokes, tars, and other substances were used. There were only four main repellents accessible before WWII: citronella oil, which was sometimes used as a hair remedy for head lice, dimethyl phthalate, which was found in 1929, Indalone, which was patented in 1937, and Rutgers 612, which was marketed in 1939(8). The latter three components were combined into a military composition known as 6-2-2 at the onset of World War II; six parts dimethyl phthalate, two parts Indalone, and two parts Rutgers 612. During the war, other military repellent formulas for use on garments were created, but they all failed to provide the protection that military soldiers stationed around the world required. As a result, the US government had investigated over 20,000 possible mosquito repellent chemicals by 1956(9). N,N-diethyl-m-toluamide (DEET) was discovered to have insect repellent characteristics in 1953, and the

first DEET product was produced in 1956. The most extensively used mosquito repellent is still DEET. Although it is usually thought to be safe, side effects have been reported, including encephalopathy in children, urticaria syndrome, anaphylaxis, hypotension, and slowed heart rate (10).

Types of repellent

Mosquito repellents are classed in a variety of ways. Depending on their source, they are categorized as chemical or herbal repellents. They can also be categorized according to how they act. Insecticides that repel insects and pests rather than killing or killing them are known as repellent insecticides. During Contact Insecticides are chemicals that include neurotoxins that disrupt mosquito and insect nervous systems and render them unconscious when they come into contact with them(11).



Synthetic mosquito repellents

According to Brown and Hebert, the synthetic compound DEET (N, N-diethyl-mtoluamide) has been the most effective single insect repellent for many years and is the basis for many commercial mosquito repellent products on the market. Despite reports of major toxic qualities that can have a significant impact on adults and children, such as dermatitis, allergic reactions, neurological (seizures, coma), and cardiovascular toxicity, the likelihood of serious toxic consequences of DEET is deemed low. DEET, on the other hand, should be used at the lowest effective amount feasible. Effective mosquito repellents such as dimethyl and di-n-butyl phthalates (DMP and DBP, respectively) were widely used in the previous century but are no longer frequently advised due to their toxicity (12).

Sr. no	Chemicals used in Repellent	Limitations
1.	DEET	□ Skin irritation □ Toxic Can dissolve synthetic fabrics as it is an effective solvent
2.	Picaridin	□ Toxic to aquatic life □ Eye irritation
3.	Allethrins	Low toxicity towards humans and birds but high toxicity level towards aquatic life

Table no 1: Extensively used mosquito repellents and their limitations

Needs of Herbal mosquito repellent

Despite the widespread use of DEET-containing products, researchers such as Tenenbein and records from poison control centre telephone data have reported and found only a few cases of dermatitis, allergic reactions, and neurologic and cardiovascular toxicities such as seizures following the use, ingestion, and high-concentration use of DEET on children and adults (13,14,15). Other negative health effects have been documented, including encephalopathy, tremor, slurred speech, behavior abnormalities, coma, and even death (13, 16, 17).

Plant based repellent:

Natural products have proven to be a rich supply of molecules for therapeutic development, with greater structural diversity on a bigger scale than synthesized compounds. Natural products have historically been important sources of bioactive compounds and will continue to be important in the development of novel medications (18). Plant-based repellents have been used as a personal protective strategy against many Anopheles species for generations in traditional practice. Traditional repellent plant knowledge is a valuable resource for developing new natural repellents as an alternative to chemical repellents.

Plant extracts or essential oils have been found to repel malaria vectors in numerous investigations all over the world. The goal of this systematic evaluation was to see if plant- based insect repellents were efficient against Anopheles mosquitoes. Some plants' essential oils and extracts could be used to create environmentally safe repellents against Anopheles species. Plant oils, which are reasonably safe, affordable, and widely available in many regions of the world, may one day serve as viable alternatives to synthetic repellents(19).

Plant essential oils such as lavender, camphor, catnip, geranium, jasmine, broad-leaved eucalyptus, Orange, lemongrass, lemon-scented eucalyptus, amyris, narrow-leaved eucalyptus, carotin, cedar wood, chamomile, cinnamon oil, juniper, cajeput, soya bean, rosemary, niaouli, olive, shows good repellent properties.

Plant oil	**Plant species**	**Part**	**Major component**	**Repellency %**	**Protection time (hours)**
Basil	Ocimum basilicum L.	leaf, flower top	estragole, limonene, fenchone, linalool, eugenol E-methyl cinnamate, 1,8-cineole(20).	66.3	3.5
Camphor	Cinnamomum camphora (L.) J. Presl	wood, bark, leaf	1, 8-cineole, α-terpineol,α-pinene, linalool, camphor, sabinene(21).	-	-
Cedar	Cedrus Trew (Cupressus L., Juniperus L.) spp.	wood	thujopsene, eudesmol, E-(+)-α-atlantone;α,β & γ-himachalenes; α- & β-cedrenes; limonene, β-phellandrene, α & β-pinene, 3 carene; p-	38.1	8

			methyl-Δ-3- tetrahydro &p-methyl acetophenones; hinokitiol, carvacrol (22).		
Chamomile	Chamaemelu m nobile (L.) All.	seed, leaf, flower	Roman: isobutyl, isoamyl & 2-methylpentyl angelates, α-pinene German: E-β-farnesene, E, E-α farnesene, α-bisabolol, α-bisabolol oxides A& B (23).	76.2	8
Citronella	Cymbopogon nardus (L.) Rendle, C. winterianus Jowitt ex Bor	leaf	citronellal, geraniol, citronellol, geranylacetate(24, 25).	100	11
Cinnamon	Cinnamomum zeylanicum Blume	bark, leaf	eugenol, cinnamaldehyde(26, 27).	100	8
Clove	Syzygium aromaticum (L.) Merr. & L.M. Perr y	flower bud	eugenol, caryophyllene, eugenyl acetate(28).	100	3.5
Eucalyptus	E. dives Schauer	leaf	1, 8-cineole, p- menthane-3,8-diol, α- pinene, p-cymene, γ-terpinene, eucamalol, allo-ocimene,	28.6	5.5

			citronellol, α-terpineol (29).		
Geranium	Pelargonium graveolens L'Hér.	leaf, stem	2-phenylethanol, geraniol, citronellol, geranyl acetate (30).	61.9	8
Jasmine	Jasminum grandiflorum L.	flower	linalool, benzyl acetate,methyl & benzyl benzoates, methyl anthranilate, Z-jasmone, eugenol(31,32).	100	8
Juniper	Juniperus communis L.	fruit	α-pinene, myrcene, sabinene, germacrene D(33).	76.2	8
Lavender	Lavandula angustifolia Mill.	flower	linalool, linalyl acetate, lavandulyl acetate, α- terpineol, geranyl acetate, terpinen-4-ol, 1,8-cineole(34,35).	80.9	8
Lemon	Citrus × limon (L.) Osbeck	peel	limonene, β-pinene, γ-terpinene(36).	9.5	7
Lemongrass	Cymbopogon citratus (DC.) Stap	leaf	geranial, neral,myrcene (30).	100	8
Lemon eucalyptus	Eucalyptus citriodora Hook.	leaf, twig	citronellal, citronellol(37).	52.4	8
Peppermint	Mentha × piperita L.	Aerial part	isomenthol, p-menthone, isomenthyl	100	11
			& menthyl acetates(38, 39)		
Rosemary	Rosmarinus officinalis L.	Flowe r	verbenone, camphor, borneol, bornyl acetate, α-terpineol, terpinen-4-ol (40)	100	8
Orange	Citrus Sinensis	Peel	limonene, myrcene (41)	100	2

Table no 2: Parte of plants with their compositions

HERBAL METHOD FOR MOSQUITO REPELLENT FINISH

Herbal repellents are preferable than chemical repellents since they are non-toxic, non- allergenic, and environmentally friendly. On use herbal repellent, first make herbal extracts, then apply those extracts to fabrics.

1. HERBAL EXTRACT EXTRACTION

Fresh herbs are separated and shadow dried before being pounded into a fine powder. For extraction, a sufficient amount of dry powder is mixed with solvents such as methanol, ethanol, hexane, or water and maintained in a closed container overnight, for a few days, or for a few hours. The extract is subsequently filtered using filter paper. The herbal extracts are condensed by evaporating the solvents and kept for subsequent use after filtration (42, 43).

2. APPLICATION OF HERBAL EXTRACTS

DIRECT APPLICATION METHOD

The produced extract is immediately applied to the fabric utilizing the pad-dry-cure procedure in this method. The fabric is squeezed, dried, and cured after being padded with extract (44, 45).

METHOD OF MICROENCAPSULATION

Herbal extracts are encased in microcapsules in this process. The exhaustion procedure isthen used to finish the fabric. The cloth is soaked in the microcapsule solution for a short period of time before being removed, squeezed, dried, and cured (44, 46, 47).

Basil

Steam distillation in a Clevenger-style equipment was used to get the oils. Their chemical composition was determined via gas chromatography mass selective analysis. The antioxidant activity of these essential oils was determined using 1, 1-diphenyl-2-picrylhydrazyl assays; the tyrosinase inhibitory abilities of the given group of oils were also determined spectophotometrically; and the antimicrobial activity of the essential oils was determined using the agar diffusion method, with minimal inhibitory concentrations expressed (48).

Camphor

Camphor is a common substance that can be used to kill mosquitoes in a home. When compared to other natural products, this substance, which is made from a tree extract, has the longest mosquito repellent effect. In a closed environment, burning camphor can be very efficient at repelling insects (49).

Cedar

The mosquito Aedes aegypti was not repelled by cedar wood oil (50).

Chamomile

The relaxing effects of dried chamomile leaves and flowers help to relax our nervous system and induce a deep natural slumber. Chamomile not only repels ticks and mosquitoes, but it also repels flies (51).

Citronella

Citronella is an essential oil derived from the leaves and stems of one of the lemongrass species of plants. Citronella oil is released when the leaves and stems of this plant are crushed, and it is utilised as a natural insect repellent. Citronella oil is used to repel mosquitoes in a variety of ways, including directly applying the oil, using infusers, and so on (52).

Citronella (Cymobopogon nardus) is a common repellent component. Citronellal and geraniol, both of which repel pests, are abundant in this oil. When coupled with other essential oils, products with the optimum proportion of citronella can be as effective as DEET.

Cinnamon

Cinnamon is useful for more than simply applesauce and oatmeal. Cinnamon oil has been shown to kill mosquito eggs in a study conducted in Taiwan.

Adult mosquitoes, particularly the Asian tiger mosquito, can be deterred by it (53).

Cinnamon has been recommended for use as an insect repellent. Cinnamon oils and their constituents, such as cinnamaldehyde, are insecticidal chemicals that have been used to control a wide range of insects. Cinnamon leaf oil was found to be a particularly powerful mosquito larvae killer. Cinnamaldehyde, cinnamyl acetate, eugenol, and anethole, all of which are contained in cinnamon leaf oil, have been proven to be the most efficient against mosquito larvae. Filter paper diffusion and fumigation procedures were used to test the insecticidal and fumigant characteristics of C. cassia bark-derived compounds against the oak nut weevil (Mechoris ursulus) (54).

Clove

Clove oil has been examined for its antibacterial, antimicrobial, and antifungal effects against cutaneous infectious symptoms, and has been found to be ecologically safe and harmless to people, making it suitable for usage in medicine, perfume, and food flavouring (55).

Respected authorities, such as the AAP, must endorse the proposal. For insect repellent needs, health care experts may be able to prescribe natural clove oil as an alternative to the currently suggested insect repellent DEET.

Eucalyptus

Water distillation in a Clevenger apparatus was used to extract Eucalyptus globulus essential oil. For the repellency test, Culicidae larvae were collected and adult mosquitoes were raised. The water titration method was used to prepare micro-emulsions of Eucalyptus globulus essential oil by mixing the prescribed surfactant (Tween 80 and Span 20) with the right amount of co-surfactant (propylene glycol). The time of protection of essential oil micro-emulsion against mosquitoes was estimated using the laboratory method of arm in cage and DEET as a standard repellent.

At a concentration of 15% w/w, a prepared micro-emulsion of eucalyptus oil has potential repellency comparable to DEET. In terms of thermodynamics and kinetics, nano-sized microemulsions appear to be stable. Finally, the use of nano-sized microemulsions can help to prolong the volatility of eucalyptus essential oil and volatile oil release from formulations, extending mosquito protection time (56).

Geranium

Because geranium oil isn't on the EPA's list of approved repellent substances,it isn't tested for effectiveness. It is, nonetheless, one among the most often used essential oils in natural repellents.

Bite Blocker is a well-known brand that uses geranium. The effectiveness of this organic repellant has ranged from little over one hour to as much as seven hours in trials. The combination of rose geranium oil and coconut oil is thought to contribute to its effectiveness, albeit neither is as effective as DEET alone (7).

Jasmine

Jasmine essential oil produced from Jasminum grandiflorum L. has been shown to repel mosquitos in experiments. Only three research have examined the mosquito repellent effectiveness of Roman chamomile essential oil, despite the fact that its chemical makeup has been identified (57).

Juniper

In tests, jasmine essential oil derived from Jasminum grandiflorum L. was found to repel mosquitos. Despite the fact that the chemical makeup of Roman chamomile essential oil has been known, just three studies have looked at its mosquito repellent potential (58).

Lavender

Even though the smell of lavender oil is pleasant and comforting to humans, it may be used to repel mosquitoes. This is because lavender oil contains natural insect repellents such as limonene, linalool, eucalyptol, and camphor (36, 37).

Lemongrass

Lemongrass is a citrus herb with a mild flavour. It's a common element in tea and a variety of Asian dishes.

Researchers discovered that a blend of lemongrass essential oil and olive oil gave 98.8% protection against the southern house mosquito in a trial (59). During a field trial, Trusted Source discovered that a topical application of lemongrass essential oil offered 74–95 percent protection against two species of mosquitos for 2.5 hours (60).

Lemon eucalyptus

85% citronellal is found in lemon eucalyptus essential oil. Because of its fresh aroma, it is a popular cleaning and cosmetics product.

Lemon eucalyptus oil has been shown to protect against numerous types of malaria-carrying mosquitos as well as the yellow fever mosquito in both field and laboratory trials.

According to a study, a combination with 32 percent lemon eucalyptus oil provided at least 95 percent mosquito protection for three hours. Because it dissipates more quickly than DEET, it provides less protection for a shorter period of time (61).

Peppermint

Another natural technique to repel mosquitoes is to use peppermint. The Source came to the conclusion that large doses of peppermint essential oil are helpful, but no study on lower concentrations could be found (62, 63).

Peppermint essential oil was found to be effective against mosquito larvae and to provide 100 percent protection against adult yellow fever mosquito bites for up to 150 minutes in a research.

Rosemary

Rosemary leaf (Rosmarinus officinalis L) is a plant that contains geraniol, linalool, sineol, and burneol, among other essential oils. Essential oils are used to repel insects. This study focuses on a repellent test using Rosemary (Rosmarinus officinalis L) gel for Aedes aegypti mosquitos, with the goal of determining whether Rosemary (Rosmarinus officinalis L) can be used as a repellent preparation for Aedes aegypti mosquitos (64).

Orange

Important micronutrients, such as vitamins C and E, as well as carotenoids and flavonoids, are found in the human diet and are necessary for maintaining human health. Almost all plant material contains many dietary sources for these chemicals (65, 66). The presence of these functional food elements and antioxidant nutraceuticals or phytochemicals contributes to the nutritional value of foods. Phytochemicals are found in edible fruits and vegetables, and when consumed, they may help to regulate human metabolism and avoid chronic and degenerative diseases (67, 68). Citrus fruits are the primary source of key phytochemical components and have long been prized for their nutritional and antioxidant characteristics. Oranges' high vitamin and mineral content has been scientifically demonstrated to provide numerous health benefits. Furthermore, other biologically active, non-nutrient compounds found in citrus fruits,

such as phytochemical antioxidants and soluble and insoluble dietary fibres, are now recognised as beneficial in lowering the risk of cancer, as well as many chronic diseases such as arthritis, obesity, and coronary heart disease (69, 70).
Orange itself is boon as its repellent activities against various insects such as cockroaches, beetle mosquitoes, etc. The seeds and powder of its peels is used in various ways in controlling pests in storage. Its seeds and peels contain certain compounds which varied the level of bitterness and these compounds have been tested against insects and proved to be effective. The beneficial roles of orange are as follows:

- Antibacterial activity
- Source of vitamin C
- Antifungal activity
- Antioxidant activity
- Anti-Obesity activity
- Activity in cardiovascular system
- Protective of UV activity
- Relaxant, Sedative and Anxiolytic activities
- Insecticidal activity

Orange oil can be used as green pesticides for biological pest control. It can exterminate or control ants and other insects by erasing their scent-pheromone trail indicators, or melting their exoskeleton, eliminating the infestation or disrupting re-infestation. Dry wood termites (Incisitermes.) are also reported to be controlled, but not exterminated, by orange oil, which kills only those who come into close contact with it. It is also used in various cosmetic formulations such as creams, lotions, perfumes, etc. Orange oil is said to have a variety of benefits in aromatherapy, including the ability to reduce stress, manage anxiety, facilitate relaxation, and improve mood. Citrus oils are composed up of extremely volatile terpenes and oxygenated molecules (71).A hesperidium, or berry, is the orange fruit. The orange, like all citrus fruits, is acidic, with a pH range of 2.5–3, depending on the age, size, and variety (72). Although not as strong as the lemon on average, it is still fairly strong on the scale—almost as strong as vinegar. Orange oil is an essential oil produced by glands within an orange's rind. As a by-product of orange juice production, it is extracted or steam distilled. Because it is predominantly D-limonene (more than 90%), it is frequently substituted for pure D-limonene, which may be extracted further from the oil by distillation (73, 74).

According to our study and literature survey it can be also used as mosquito repellent due to its characteristic odour as compared to synthetic mosquito repellents as it is natural and with low risks of side effects (75, 76).

Discussion

Because pests and vectors are chemically controlled, a high level of pesticide resistance has developed. Alternative vector control approaches must be investigated in order to solve this challenge. People seek mosquito repellents that are safe, easy to use, and environmentally sustainable, so the field of herbal repellents is ready for development. Given the importance of cost, it is highly recommended that the use of native flora as repellents be investigated. Essential oils and plant extracts are gaining traction as potential Anopheles spp. control agents due to their ease of use, low cost, and lack of risk. In this systematic review, limonene and linalool were determined to have the greatest repellency effect against Anopheles mosquitoes and was majorly found in Basil, camphor, cedar, jasmine, lavender, lemon, orange oil with complete protection time ranging from 9 to 11 hours also essential oil from chamomile, citronella, cinnamon, clove, eucalyptus, geranium, juniper, lemon grass, lemon eucalyptus, peppermint, rosemary showed good repellency effect 8 hours complete repellency against different species of anopheles mosquito.
The exact mechanism of action of these plants in preventing bites by Anopheles spp. has yet to be determined. It is believed that active components in citronella extract for repelling mosquitoes are eucalyptol, camphor, linalool, citral, and citronellal, which is one of the most researched plants for repellency effect against various mosquitoes (77). Some evidence suggests that these chemicals interfere with mosquito olfactory receptors (78). An. gambiae can detect citronellal compounds via olfactory neurons in the antenna controlled by the TRPA1 gene, which are activated directly by the chemical with high potency, according to a recent study (79, 80). Citronellal directly activates cation channels, according to another study, which is comparable to the excite-repellent effect of pyrethrin, another plant-based terpine (81), but differs from DEET's inhibitory effect. Citronella oil provides protection for a shorter period of time than DEET (82). Citronella oil has the potential to give mosquito protection for an extended period of time. The underlying mechanism for other plants is still unknown. Enhanced formulations of plant extracts to elevate their lifetime through the invention of nanoemulsions, improved formulations, and fixatives may be the most essential feature in raising the permanence of such repellents that are effective but volatile. Excite-repellency and spatial activity are two further applications that have been investigated (83).

Conclusion

The findings of this study revealed that essential oils and extracts from certain plants have strong repellent action against Anopheles spp. mosquitoes. In the last two decades, researchers have been looking for novel natural repellents, and while certain plants have shown to have repellent properties, few natural products have been developed. Entomologists and individuals working in the field of mosquito-borne diseases should read this review to learn more about the usefulness and possible role of plant-derived repellents in disease control.

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