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Review Article

A REVIEW ON: MOSQUITO REPELLENT METHODS CONTAINING DIFFERENT ESSENTIAL OILS

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ABSTRACT

M*osquito borne illnesses such as dengue, chikungunya, filariasis, malaria and japanese B encephalitis causing millions of deaths every year. Personal protection from mosquito bites and mosquito control are currently the most important measures to be taken to prevent these diseases. To overcome all these, mosquito repellants are used. Essential oils from plants have been recognized as important natural resources of insecticides because of their selectiveness, biodegradability to non-toxic products and have few effects on non-target organisms and environment. Lactic acid and carbon dioxide present in sweat in warm- blooded animals act as an attractive substance for mosquitoes. The odor perception is through the chemoreceptors present in the antennae of the mosquitoes. Insect repellents work by masking human scent, a number of natural mosquito repellents including essential oils were studied in this review that work to repel mosquitoes. The essential oils are volatile mixtures of the hydrocarbons with a diversity of functional groups, and their repellent activity has been linked to the presence of mono - terpenes and sesquiterpenes. In some cases, these chemicals can work synergistically, improving their effectiveness. The aim of this review is to highlight the significance of essential oils from the plants and mosquito repellant methods implemented for them.*

KEYWORDS: *Mosquito Repellent, Essential Oils, Dengue, Chikungunya, Filariasis, Malaria and Japanese B Encephalitis.*

INTRODUCTION

The control of mosquitoes remains a challenge even after continuous use of synthetic insecticides in public health. Vector borne diseases are infections transmitted by the bite of infected arthropod species. Industrialized farming and deforestation can also be considered as factors responsible for alarming increase in the range mosquitoes [1-3].

A number of natural and chemical mosquito repellents were studied that work to repel mosquitoes. As frequent and repeated use of chemical mosquito repellents has resulted in the development of mosquito repellent resistance and toxic effects on human beings which include rashes, swelling, eye irritation, and worse problems, though unusual including anaphylactic shock and low blood pressure. There are number of essential oils used as mosquito repellents having repellency from several minutes to several hours. Essential oils are volatile naturally occurring, complex compounds characterized by a strong odor and are formed by plants as secondary metabolites [1, 3-5].

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Essential oils as insect repellents in general and mosquitoes in particular:

General:

It may be useful to attempt a brief review of some of the scientific literature available on essential oils as mosquito repellents. In terms of popularity, citronella oils from *Cymbopogon nardus* and *C. winterianus* have been reported to be the most widely used insect repellents (Hermes & James 1961). These oils naturally contain (4R)-(+)-(b)-citronellol and (mainly) (3R)-(+)-b-citronellal which appear to be the principle actives. Although these oils are effective and of relatively low cost, not everyone cares for the somewhat crude odour profile of citronella oils, especially the Sri Lanka sourced oil (from *Cymbopogon nardus*). However in terms of efficiency, Dr. David Sullivan of Johns Hopkins Bloomberg School of Health in Baltimore, Md., reports that Soy oil is in fact the most useful of the plant-based mosquito repellents (United Press International 2003) [3, 6-9].

In parts of Scotland, the Highland Midge *Culloides impunctatus* can make life miserable for locals and holidaymakers alike. The use of endemic aromatic plant *Myrica gale,* the volatiles from which having a high 1,8-cineole content, has been well reported for midge repellency (Simpson et al 1996; Stuart 1990; McGhee 1975). The essential oil for use against midges is sold under the name of "Myrica" by Scotia Pharmaceuticals [7, 9, 10-14].

Differences in susceptibility across a range of different mosquito species, to six separate agents (diethyl toluamide

[DEET], dimethyl phthalate, ethyl-hexanediol, permethrin, citronella and cedarwood oils) were investigated by Curtis et al. (1987) [15, 16]. The authors found that general susceptibility decreased in the series *Anopholes stephensi*, *A. gambiae*, *A. albimanus* and *A. pulcherrimus*. DEET-impregnated anklets gave 84% protection in 2-hour tests against *Culex quinquefasciatus* and *A. funestus*but protection was less impressive against *A. gambiae, A. coustani* and *Mansonia* spp [10, 14, 17-22].

As well as differences in species susceptibility, the choice of a superior natural repellent is the driving force of many published articles. It is widely assumed that repellents act by blocking receptors on the hairs of mosquito antennae which detect body heat, moisture and carbon dioxide, causing disorientation and loss of targeting ability [24-26]. Conclusions about the absolute efficacy of individual oils as repellents are hard to deduce from the mass of data, since the botanical, geographical, chemotype and composition of the oils used are rarely defined. All-day repellency from a simple single topical application of an essential oil or mixture is a high expectation, given the relatively high rate of evaporation/absorbtion of essential oils from, or into, the skin [27, 28]. Thus synthetics with a longer dermal surface residence time, such as DEET, may offer an advantage [3, 14, 22, 29-34].

Nevertheless, several articles multi-screen a number of essential oils for mosquito repellency, with mixed outcomes. Girgenti & Suss (2002) used five commercial repellents based on essential oil mixtures including containing citronella, clover, eucalyptus, geranium, lavender, peppermint, sandalwood and thyme, reporting poor repellency (less than or equal to one hour) against the mosquito *Aedes aegypti,* whereas a synthetic repellent afforded better protection. Similar conclusions were drawn by Primavera Laboratories (1999) reporting on their trials leading to an insect repellent patent. The company reportedly used seven subjects in a total of 1210 trials using *Aedes aegypti* mosquitoes [35-38]. The best combination was said to consist of 7% citronella (oil), 9% geraniol, 9% terpineol and 75% "Chinese crystal" at about 1-5%, where the identity of "Chinese crystal" was stated to be a natural 3-hydroxy-a,a,4-trimethylcyclohexanemethanol isolated from a particular Chinese essential oil. Twenty essential oils were screened by Cora *et al*. (1993) against the mosquito (*Aedes aegypti*), fruit fly (*Drosophila melanogaster*) and the house fly (*Musca domestica*), where the oils of *Juniperus communis, Valeriana officinalis, Thymus vulgaris, Solidago graminifolia, sylvestris, Coriandrum sativum, Larix decidua, Pseudotsuga menziesri, Tanacetum vulgare* and *Abies alba* were all found to be highly repellent to mosquitoes [21, 24, 39-46].

Tawatsin *et al.* (2001) investigated the repellency effects of essential oils of turmeric (*Curcuma longa*), keffir lime (*Citrus hystrix*), citronella grass (*Cymbopogon winterianus*) and hairy basil (*Ocimum americanum*), against the mosquitoes *Aedes aegypti*, *Anopheles dirus* and *Culex quinquefasciatus* both in caged and open room conditions. The oil of Keffir lime either alone or with 5% vanillin added, repelled mosquitoes in cage conditions for up to three hours. Turmeric, citronella and hairy basil oils especially with the addition of 5% vanillin, repelled the three species under cage conditions for up to eight hours, comparing well against the DEET standard which provided protection for at least eight hours against *A. aegypti* and *C. quinquefasciatus*, but for six hours against *A. dirus*. Incorporating 5% vanillin with DEET gave protection against the three mosquito species for at least eight hours. The large room experiment confirmed the findings of the cage experiment. The authors concluded that it is possible to formulate with essential oils as a DEET replacement [3, 11, 47-54].

Girgenti & Suss (2002) compared five commercial mosquito repellents – four of which were natural oil formulations (containing citronella, clover, eucalyptus, geranium, lavender, peppermint, sandalwood, thyme, etc.) and one which was a synthetic chemical repellent containing 10% KBR 3023 in cream or lotion. Tests were performed on adult male and female human volunteers in laboratory based testing conditions. The natural oil products showed either poor (protection time less than 1 hour) or no repellency against *A. aegypti*, in contrast to the synthetic repellent, which performed satisfactorily. It is interesting to speculate separately on why unsatisfactory results were obtained here – reliance on particular items from a specific batch of commercial oil product obviously has its' pitfalls, but it may be that the problem centers around topical dosing levels (i.e. concentration of the oils in the application vehicle) [51-56].

Studies on alcohol extracts may tell us more about other classes of actives capable of isolation from aromatic plants, as well as the essential oil content. Govere *et al*. (1993) used "essential oils" from local South African plants against *Anopheles arabiensis*, finding that alcohol extracts of *Lippia javanica*, *Pelagonium reniforme* and *Cymbopogon excavatus* all protected against *Anopheles arabiensis* mosquito bites; the repellent effect of fever tree oil (*Lippia javanica*) lasted significantly longer – and also happens to be the only commercially available oil, notwithstanding that several chemotypes of the oil are known [1, 2, 55-57].

Corbet *et al*. (1995) investigated the larvicidal mode of action of essential oils, who notified the susceptibility of mosquito larvae and pupae to surface materials entering their tracheal system, observing that essential oils increased the tendency to tracheal flooding and chemical toxicity. They reasoned that the addition of surfactants would increase the oil concentration in water and spreading pressure, and set out to prove this with a mixture of eucalyptus, turpentine and cineol, and arosurf, an insoluble surfactant. The authors were also able to establish that all three substances were larvicidal, and their action was greater when Arosurf and a detergent were added. The initial level of activity of the oil was greater than for a commercial larvicide, but mortality over a 1-2 day period was lower. This seems to be a promising line of investigation using moderately cheap aromatic raw materials. The potential of garlic oil as a non-toxic mosquito larvicide has been reviewed by Klocke (1989) [1, 3, 56-60].

Essential oils which have better mosquito repellency includes Citronella oil, Neem oil, Eucalyptus oil, Lavender oil, Peppermint oil. Their active ingredients and insecticidal uses are shown as follows: [3]

Citronella oil: (Cymbopogon winterianus Jowitt.)

Active Components: *C. winterianus* essential oil is very rich in citronellal, geraniol and citronellol. There are other constituents aiso like citronellyl acetate, L-limonene, ellemol and other sesquiterpene alcohols present in citronella.

Uses: Citronella oil repels insects such as mosquitoes, black flies, fleas and ticks, therefore, preventing its bites, hence can be used as a repellant. It is used on humans and their clothing in

the form of oil, liquid and patches. Citronella oil is a natural, non-toxic alternative to chemical insect repellents such as DEET, therefore, is usually the preferred choice [4-6].

Neem oil: (Azadirachta indica)

Active Components: Azadirachtin, Nimbin, Nimbidin, Nimbidol, Sodium nimbinate, Gedunin, Salannin, Quercetin.

Uses: Neem's natural mosquito repellent properties are an important weapon in the fight against malaria. Kerosene lamps with 1% neem oil can protect people from mosquito bites. The protection was greater against *anopheles* species. Concentrations of 2% neem oil mixed in coconut or mustard oil provides 100% protection against *Phlebotomus argentipes* throughout the night under field conditions [48-51].

Lavender oil: (Lavandula angustifolia)

Active Components: The medicinal components present in it are linalool, linalyl acetate, cineol, pinene, limonene, geraniol, borneol, tannins.

Uses: They can be used for larvicidal and pupicidal activities against the house fly. the essential oils of peppermint and lavender in combination have a control potential against insecticidal activity [52-54].

Eucalyptus oil: (Eucalyptus globules)

Active Components: Eucalyptol, Ethyl alcohol, Amyl alcohol, Camphene, Eudesmol, Phellandrene, Pinene, Aromadendrene.

Uses: Eucalyptus oil has been registered as a "biopesticide repellent" by EPA in 2000, meaning it is derived from natural materials. The resulting products can be applied to human skin and clothing for repelling insects such as mosquitoes, biting flies, and gnats. They can be formulated into sprays or lotions [55, 56].

Peppermint oil: (Mentha piperita L)

Active Components: Menthone, p-Menthane-3, 8-diol is also a major breakdown product of menthol, the alcohol in mint oils used as peppermint flavouring. p- Menthane-3, 8-diol has been registered with EPA as a mosquito repellent since 2000.

Uses: It has promising and remarkable repellent activity against *Ae. Aegypti* adults. It has a proven and established efficacy against the dengue vector larvae. It also have larvicidal activity against different mosquito species: *Aedes aegypti*, *Anopheles stephensi* and *Culex quinquefasciatus.* The oil shows strong repellent action against adult mosquitoes when applied on human skin. Percent protection observed against *An. annularis*, *An. culicifacies*, and *Cx. Quinque fasciatus* was 100%, 92.3% and 84.5% [57, 58].

Other insect repellents from natural sources:

Preparations from naturally occurring sources that are repellent to certain insects are plenty in numbers. Some of these act as insecticides while others are only repellent. Basil *Ocimum basilicum,* Castor oil (*Ricinus communis*),Catnip oil (*Nepeta* species) (nepetalactone against mosquitoes), Cedar oil (mosquitoes, moths) ,Celery extract (*Apium graveolens*) ,Cinnamon oil (leaf oil kills mosquito larvae) ,Citronella oil (repels mosquitoes),Clove oil (mosquitoes) (NB: a dose similar to the one as a food ingredient should be used for the time being.) ,Eucalyptus oil (70%+ eucalyptol), (cineol is a synonym), (mosquitoes), Fennel oil (*Foeniculum vulgare*) (mosquitoes), Garlic (*Allium sativum*) (rice weevil, wheat flour beetle) (NB: a dose similar to the one as a food ingredient should be used for the time being) ,Geranium oil (also known as *Pelargonium graveolens* Lavender (repels insects) ,Lemon eucalyptus (*Corymbia citriodora*) essential oil and its active ingredient p-menthane-3,8-diol (PMD), Lemongrass oil (*Cymbopogon* species) (mosquitoes), Peppermint oil (*Mentha* x *piperita*) (mosquitoes), Rosemary (*Rosmarinus officinalis*) (mosquitos), Solanum villosum berry juice (against Stegomyia aegypti(mosquitoes), Nepetalactone, also known as "catnip oil". Neem oil (*Azadirachta indica*) (Repels or kills mosquitoes including their larvae and a plethora of other insects including those in agriculture) [59, 60].

Table No. 1: An overview of repellent plant efficacy from literature reviews

Plant	Common names	Repellent compound (s)	Tested mode of use	Repellency % protection	Study type	Ref
MYRTACEAE *Corymbia citriodora*	lemon eucalyptus lemon scented gum quwenling	citronellal PMD (by product of hydrodistillation) (p-menthane-3,8-diol) citronellol limonene geraniol isopulegol δ-pinene	30% PMD applied topically	96.88 % protection from mosquitoes for 4 hours	field study in Bolivia	**61**
			PMD towelette (0.575g) applied topically	90% protection from *An. arabiensis* for 6 hours	laboratory study	**62**
			50% PMD applied topically	100% protection from *An gambiae*and *An. funestus*for 6-7 hours	field study in Tanzania	**63**
			20% PMD (1.7mg/cm^2) applied topically	100% protection for 11-12 hours against *A. stephensi*	laboratory study	**64**
			20% PMD applied topically	100% protection against *Ae. Aegypti* for 120 minutes	Laboratory study	**65**
			thermal expulsion (leaves are used)	78.7 % protection from the species *An.*	field study in Ethiopia	**66**

				arabiensis 76.8% protection from species *An. Pharaoensis*		
			direct burning (leaves are used)	70.1 % protection from *An. arabiensis* 72.9% protection from *An. Pharaoensis*	field study in Ethiopia	**66**
			periodic thermal expulsion (leaves)	74.5% protection from *An. gambiae*s.s.	semi-field study in Kenya	**67**
			periodic direct burning (leaves)	51.3% protection from *An. gambiae*s.s.	semi-field study in Kenya	**67**
			thermal expulsion (leaves)	48.71% protection from *An. gambiae s.l.*	field study in Kenya	**68**
***Eucalyptus* spp.**	eucalyptus	1,8-cineole citronellal Z- and α-citral α-pinene	thermal expulsion (leaves)	72.2% protection from mosquitoes for 2 hours	field study in Guinea Bissau	**69**
E. camaldulensis			thermal expulsion (leaves)	71.9 % protection from *An. arabiensis* 72.2% protection from *An. Pharaoensis*	field study in Ethiopia	**66**
			direct burning (leaves)	65.3 % protection from *An. arabiensis* 66.6% protection from *An. pharaoensis*	field study in Ethiopia	**66**
Eugenia caryophyllus* or *Syzygium aromaticum* or *Eugenia aromatic	clove lavang cravinho-da-india	Eugenol carvacrol thymol cinnamalde hyde	100% essential oil applied topically	100% protection against *Ae. aegypti*for 225 minutes 100% protection against *An. albimanus* for 213 minutes	laboratory study	**70**
			100% essential oil applied topically	100% protection against *Ae. aegypti*for 120 min. 100% protection against *C. quinquefasciatus*for 240 min. 100% protection against *An. dirus*for 210 min.	laboratory study	**71**
VERBENACEAE *Lippia* spp.	lemon bush	myrcene linalool α-pinene eucalyptol				
L. javanica		alloparinol camphor limonene α – terpeneol verbenone	5mg/cm^2 plant extract applied topically	100% protection against *Ae. aegypti for 8 hours*	laboratory study	**72**
			alcohol plant extract applied topically	76.7% protection against *An arabiensis* for 4 hours	laboratory study	**73**
L. uckambensis	fever tea		potted plant	33.3% protection against *An. gambiae* s.s	semi-field study in Kenya	**74**
			periodic thermal expulsion (leaves)	45.9% protection against *An. gambiae* s.s.	semi-field system in Kenya	**67**
			periodic direct burning (leaves)	33.4% protection against *An.*	semi-field system in	**67**

				gambiae s.s	Kenya	
			potted plant	25.01% protection against*An.gambiae* s	field study in Kenya	**68**
L. cheraliera		eucalyptol caryophyllene p-cymene				
Lantana camara	lantana spanish flag West Indian lantana Wild sage	Caryophyllene	potted plant	32.4% protection against *An. gambiae* s.s	semi-field study in Kenya	**67**
			potted plant	27.22% protection against *An. Gambiae*s	field study in Kenya	**68**
			flower extract in coconut oil	94.5% protection against *Ae. aegypti*and *Ae. Albopictus* for one hour	laboratory study	**75**
			periodic thermal expulsion (leaves)	42.4% protection against *An. gambiae* s.s	semi-field study in Kenya	**68**
Ocimum* spp. *O. americanum	Tree basil nchu avum lime basil kivum bas Myeni madongo African blue basil hairy basil	p-cymene estragosl linalool linoleic acid eucalyptol eugenol camphor citral thujone limonene ocimene and others	potted plant	39.70% protection against *An. gambiae* s.s	semi-field study in Kenya	**67**
			potted plant	37.91% protection against *An. gambiae*s.	field study in Kenya	**68**
			fresh plants combined with *O. suave* bruised and applied topically	50% protection against *An. gambiae*s.	field study in Tanzania	**76**
			periodic thermal expulsion (leaves and seeds)	43.1.% protection against *An gambiae* s.s	semi-field study in Kenya	**67**
			periodic direct burning (leaves and seeds)	20.9% protection against *An. gambiae* s.s	semi-field study in Kenya	**67**
			100% essential oil combined with vanillin 5% applied topically	100% protection against *Ae. Aegypti* for 6.5 hours1 100% protection against *C. quinque fasciatus* for 8 hours 100% protection against *An. Dirus* for 8 hours	laboratory study	**77**
O. suave			thermal expulsion (leaves)	73.6 % protection from *An. arabiensis* 75.1% protection from *An. pharaoensis*	field study in Ethiopia	**66**
			direct burning (leaves)	71.5 % protection from *An. arabiensis* 79.7% protection from *An. pharaoensis*	field study in Ethiopia	**66**
			periodic thermal expulsion (leaves and seeds)	53.1% protection from *An. gambiae*s.s.	semi-field study in Kenya	**67**
			periodic direct burning (leaves and seeds)	28.0% protection from *An. gambiae*s.s.	semi-field study in Kenya	**67**
O. basilicum			thermal expulsion (leaves)	78.7 % protection from *An. arabiensis* 79.2% protection from *An. Pharaoensis*	field study in Ethiopia	**66**
			direct burning	73.1 % protection	field study	**66**

			(leaves)	from *An. arabiensis* 70.0% protection from *An. Pharaoensis*	in Ethiopia	
			100% essential oil applied topically	100% protection for 70 minutes	laboratory study	**72**
O. kilimandaschar kum			thermal expulsion (leaves and seeds)	44.54% protection against *An. gambiae* s.l.	field study in Kenya	**68**
			thermal expulsion (leaves and seeds)	37.63% protection against *An. funestus*	field study in Kenya	**68**
			periodic thermal expulsion (leaves and seeds)	52.0% protection against An. gambiae s.s.	semi-field study in Kenya	**67**
			periodic direct burning (leaves and seeds)	26.4% protection against *An. gambiae* s.s	semi-field study in Kenya	**67**
O. forskolei			fresh plants hung indoors	53% protection against mosquitoes entering human dwelling	field study in Eritrea	**78**
Hyptis spp. Hyptis suaveolens	bushmint wild hops wild spikenard hangazimu hortela-do-campo	myrcene	smouldering on charcoal fresh leaves	85.4% repellency against mosquitoes for 2 hours	field study in Guinea Bissau	**69**
				73.2% repellency against mosquitoes for 2 hours	field study in Guinea Bissau	**69**
			periodic direct burning (leaves and flowers)	20.8% repellency against *An. gambiae* s.s	semi-field study in Kenya	**67**
Mentha* spp. *M. piperata	hortela-do-campo peppermint		100% essential oil applied topically	100% protection against *Ae. aegypti*for 45 minutes	laboratory study	**70**
M. arvensis	menta Japanese mint		100% essential oil volatilized in a kerosene lamp	41% protection indoors against *Mansonia* spp	field study in Bolivia	**79**
Thymus* spp. *Th. vulgaris	thyme	α-terpinene carvacrol thymol p-cymene linalool geraniol	α-terpinene topically	97.3% protection against *Culex pipiens sallens* for 82 min	laboratory study	**80**
			carvacrol topically	94.7% protection against *C. pipiens sallens* for 80 min		
			thymol topically	91.8% protection against *C. pipiens sallens* for 70 min	laboratory study	**80**
			linalool topically	91.7% protection agains *C. pipiens sallens* for 65 min		
			p-cymene	89.0% protection agains *C. pipiens sallens* for 45.2 min		
			100% essential oil applied topically	100% protection against *An. albimanus* for 105 minutes and *Ae. aegypti* for 135 minutes	laboratory study	**70**
			direct burning (leaves)	85-09% protection for 60-90 min	field study	**81**
Pogostemon spp.	Patchouli		100% essential oil applied	100% protection against *Ae. Aegypti*	laboratory study	

				for 120 min		
Pogostemon cablin	Oriza		topically	100% protection against *C. quinque fasciatus* for 150 min 100% protection against *An. dirus*for 710 minutes		
POACEAE *Cymbopogon* sp *C. Nardus*		citronellal	40% essential oil applied topically	100% protection for 7-8 hours against *An. stephensi*	laboratory study	**64**
			100% essential oil applied topically	100% protection against *Ae. Aegypti* for 120 min 100% protection against *C. quinque fasciatus* for 100 min 100% protection against *An. Dirus* for 70 minutes	laboratory study	**71**
			10% applied topically	100% protection against *Ae. Aegypti* for 20 minutes	laboratory study	**65**
C. martini	palmarosa	geraniol	topically (100% essential oil)	100% protection against *An. culicifacies* for 12 hours 96.3% protection against *C. quinque fasciatus* for 12 hours	field study in India	**83**
			topically (100% essential oil)	98.8% protection against *C. quinque fasciatus* for 10 hours	laboratory study	**83**
C. citratus	lemongrass oil grass	citral α-pinene	topically	74% protection against *An. darlingi* for 2.5h 95% protection against *Mansonia* spp. for 2.5 hours	field study in Bolivia	**79**
			Methanol leaf extract applied topically ($2.5mg/m^2$)	78.8 % protection against *An. arabiensis* for 12 hours	laboratory study	**83**
			100% essential oil applied topically	100% protection for 30 minutes	laboratory study	**71**
C. winterianius			100% essential oil combined with vanillin 5% applied topically	100% protection against *Ae. Aegypti* for 6.5 hours 100% protection against *C. quinque fasciatus* for 8 hours 100% protection against *An. Dirus* for 8 hours	laboratory study	**77**
C. excavatus			alcohol plant extract applied topically	66.7% protection against *An. arabiensis* for 3 hours	laboratory study	**73**
Pelargonium reniforme	rose geranium		alcohol plant extract applied topically	63.3 protection against *An. arabiensis* for 3 hours	laboratory study	**73**
MELIACEAE *Azadirachta indica*	Neem	azadirachtin saponins	direct burning (leaves)	76.0% protection from mosquitoes for 2 hours	field study in Guinea Bissau	**69**
			Periodic thermal expuls. (leaves)	24.5% protection from *An. gambiae*s.s	semi-field study in	**67**

					Kenya	
			1% neem oil volatilized in a kerosene lamp	94.2% protection from *Anopheles*spp. 80% protection from *Culex* spp.	field study in India	**85**
			2% neem oil applied topically	56.75% protection from mosquitoes for 4 hours	field study in Bolivia	**61**
ASTERACEAE ***Tagetes minuta***	Khaki weed		Topically	86.4% protection againt *An. stepehensi* for 6 hours	laboratory study	**85**
			Topically	84.2% protection against *C. quinquefasciatus*for 6 hours	laboratory study	**85**
			Topically	75% protection against *Ae. aegypti*for 6 hours	laboratory study	**85**
			fresh leaves (4Kg)	reduced human landings indoors	field study in Uganda	**86**
Artemisia* spp.** ***A. vulgaris	Mug wort worm wood St. Johns plant Old uncle henry Sailors tobacco	camphor linalool terpenen-4-ol α-and β-thujone β-pinene				**86**
A. monosperma	Felon herb Naughty man	myrcene limonene cineol	5% leave extract applied topically	100 % protection for 4 hours	field study in Egypt	**86**
CAESALPINIACEAE ***Daniellia oliveri***	churai santao santang santango		direct burning (bark)	77.9% protection against mosquitoes for 2 hours	field study in Guinea Bissau	**69**
			direct burning (bark)	77% protection against mosquitoes	field study in The Gambiae	**86**
FABACEAE ***Glycine max***	Soya		2% soya bean oil	100% protection against *Ae. aegypti*for 95 minutes	laboratoty study	**65**
RUTACEAE ***Zanthoxylum limonella***	makaen	Xanthoxyline Lupeol Xanthoxyletin Osthol Scopoletin Rutaecapine Triterpene Limonene	100% essential oil applied topically	100% protection against *Ae. aegypti*for 120 min 100% protection against *C. quinque fasciatus*for 170 min	laboratory study	**71**
			10% essential oil combined with 10% clove oil	100% protectio nagainst *An. dirus*for 190 minutes	laboratory study	**63**
Citrus hystrix	Kaffir lime Limau purut		100% essential oil combined with vanillin 5% applied topically	100% protection against *An. stephensi* for 8 hours 100% protection against *Ae. aegypti*for 3 hours 100% protection against *C. quinquefasciatus*for 1.5 hours 100% protection against *An. Dirus* for 2.5 hours	laboratory study	**77**

ZINGIBERACEAE ***Curcuma longa***	Turmeric Curcuma Indian saffron	Curcumin	100% essential oil combined with vanillin 5% applied topically	100% protection against *Ae. Aegypti* for 4.5 hours 100% protection against *C. quinque fasciatus* for 8 hours 100% protection against *An. Dirus* for 8 hours	laboratory study	**77**

Advantages of natural repellants:

Non-sticky; non-toxic and environmentally friendly; safer on sensitive skins and some can be used on children as young as 3 months; reduced irritation; harmless to most plastics and fabrics [18, 19, 46, 47].

Disadvantages of natural repellants:

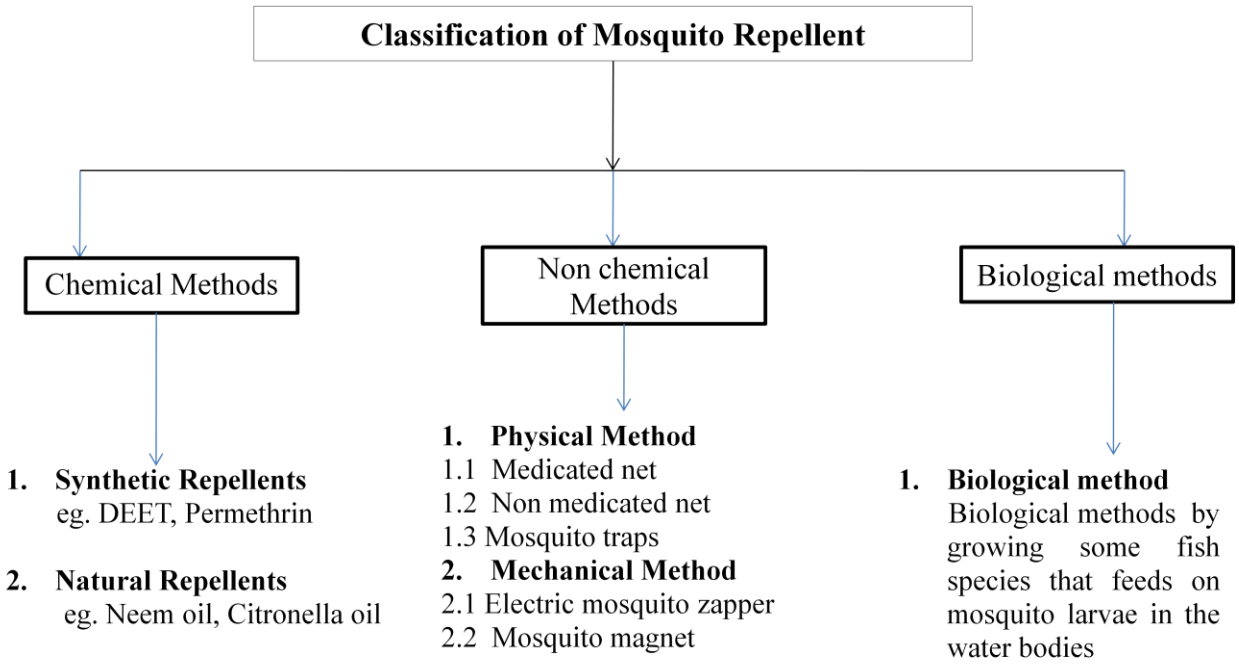
- More expensive; may need more frequent re-application to maintain full protection.
- Essential oil repellents can be short-lived in their effectiveness, since essential oils can evaporate completely may need more frequent re-application to maintain full protection
- Cannot apply directly on the skin, if applied can cause rashes on skin [18, 19, 47-49].

Definition of mosquito repellent:

A mosquito repellent is a substance applied to skin, clothing, or other surfaces which discourages insects (and arthropods in general) from climbing or landing on that surface. Depending on the sound production, particularly ultrasound (inaudibly high frequency sounds) [18, 50-52].

Mechanism of action of mosquito repellents:

The excretory products, carbon dioxide and lactic acid present in sweat in warm blooded animals act as an attractive substance for female mosquitoes. The odor perception is through chemo-receptors which are present in the antennae of mosquitoes. The repellents block the lactic acid receptors thus destroying upwind flight and as a result the mosquitoes loses its contact with the host Usually insect repellents work by masking human scent or by using the scent which insects naturally avoid. The permethrin is anyways different in that it is actually a contact insecticide [20, 53-68].



Some preparations of repellent compounds: [18, 46, 47, 59, 60, 78-82]

Mosquito repellents have been very commonly embodied in creams, lotions, pastes or other preparations, either to facilitate their application or to ensure a more lasting effect, some of them are described as follows:

Creams (ointment type):

Admixtures of the repellent with some solid greasy base such as hard and soft paraffin, petroleum jelly, cetyl alcohol, lanolin, magnesium stearate with or without modifying materials. Early repellent creams were mostly of this type.

Lotions:

They are the mixtures containing the repellent dissolved in or diluted with alcohol or other thin fluid and thickened with castor oil or arachis oil.

Creams (vanishing cream type):

They are the essential oil in water emulsions which 'disappear' on application seeming to be absorbed by the skin, largely due to evaporation of the watery phase during

manipulation. The main requirements for these are oily or greasy base, an emulsifier such as triethanolamine, triton X, etc. and water.

Creams (waxy base type):

They are the mixtures of repellent with wax and solvents (which may be the repellent itself) as if necessary to give a correct consistence.

Gum tragacanth preparations:

There are number of creams or pastes of gum tragacanth that has been employed as vehicles more especially for pyrethrum. After drying they leave a thin adherent film which is not dislodged by sweating. These kind of preparations would be unsuitable for repellents of these preparations creams of the ointment type have frequently been noted as greasy and unpleasant in a hot climate though some, e.g. stearate cream can be given as an example under this head and are cosmetically excellent. Paraffin's use as a base has been common in citronella preparations and appears to have a reducing effect on the repellency. Vanishing creams have not generally been found satisfactory because of their 'disappearing' property, unless used in large amount, they are apt to give patchy distribution of the repellent. A waxy cream can be most effective in prolonging repellent effect and if they are found to be of suitable consistency then such creams spread extremely well.

Recent Advances in Mosquito Repellent Methods:

Fogging:

Method of controlling mosquitoes, flies and other such pests is temporary by the use of fogging but is indeed necessary in many instances, including health threats from severe bug populations and to prepare for an outdoor activity where these pests are mainly unwanted for the particular. As opposed to a cold fogger, a thermal fogger produces a pesticide fog or smoke by heating the fogging solution with a coil inside of the unit. When this coil gets warmed up, it produces a nice insect fog that is directed to areas where you would like to kill mosquitoes, ready-to-use fogging solution, each gallon contains 0.5% Pyrethrins and 5.0% Piperonyl Butoxide [18, 46, 60, 84, 85].

Mosquito Patch™ a 2×2 in body patch that uses a revolutionary **transdermal technology** to deliver a natural mosquito repellent nutrient directly into the blood stream for a complete 24-hour mosquito protection. Mainly the ingredient which found to be beneficial in the patch preparation is **Vitamin B1 or Thiamine**. Thiamine is known to be the most effective.[17, 18, 60, 86]

CONCLUSION

The study on review of mosquito repellent methods containing different essential oils revealed that the natural mosquito repellents made with the help of essential oils are the best methods to repel mosquitoes as compared to synthetic methods, naturally occurring botanical compounds contain a broad range of chemical active ingredients which can intervene in all biological processes of the mosquito, thus it interrupts its life cycle and dispersal and therefore reduces harm to humans and animals. Number of medicinal plants found to be beneficiary and were tested for their pesticide and repellent potential, as crude material, essential oils or individual active ingredients. Essential oils are natural volatile substances found in a variety of plants, the only disadvantage of natural mosquito repellents is that it can evaporate completely, hence may need more frequent reapplication to maintain full protection and can be overcome by formulating different dosage forms of volatile oil like creams, ointments, lotions using various water removable bases.

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