REVIEW ARTICLE

Anti-termite and therapeutic uses of various plant essential oils from family Rutaceae: A review

Lokpriy Pandey, Ravi Kant Upadhyay

Department of Zoology, Deen Dayal Upadhyaya Gorakhpur University, Gorakhpur, Uttar Pradesh, India

Abstract

This review article explains the use of various plant essential oils (EOs) and its formulations in termite control. Plant EOs and its components show multiple deleterious effects such as toxic, antifeedant, repellent, growth, and reproductive inhibitory activity in number of insect pest species. These active components delay egg maturation and development in insects. Plant EOs constituents display contact and systemic action and primarily used as poison baits to control soil termite. This article points out the importance of the use of plant origin termiticides/ biopesticides and botanical methods to control termite menace. These alternate methods could be used to minimize the risk of poisoning of food chain, soil, and aqueous environment. This article also suggests wider use of EO-based multicomponent low-cost anti-termite formulations/methods to replace highly toxic synthetic pesticides.

Key words: Essential oils and poison baits, natural, polyphagous pest, synthetic, termites, termiticides

INTRODUCTION

Termites are major polyphagous pests causing considerable damage to agriculture crops, forestry, and household and building materials round the globe except few cold regions. Termites are detritus feeders and feed on dead leaves, stems, barks, and field crops. Termites are known as silent destroyers because of their ability to chew wood, clothes, and harm to crop fields. There are about 2000 known termite species in the world. Termites cause economic damage to commercial wood, fibers, cellulose, sheets, and papers. They also cause harm to clothes, woolens and mats, and woody building material and infest green standing foliage, and cereals stored in godowns. Termite damages approximately $32 billion in property damage annually. Termites digest plant litter in garden soil and form humus. Termites are the natural food of reptiles, birds, and mammals. Termites are used as feed for poultry. Fungus gardens and soil of termitarium are used to culture mushrooms.

The Indian white termite, *Odontotermes obesus* (Rambur) (*Isoptera*: *Odontotermitidae*), is highly destructive polyphagous insect pest in East Uttar Pradesh. It damages commercial wood, food crops, orchard plants, and household articles. Colonies are composed of casts: A queen, a king, soldiers, and workers. Some species of termite cultivate specialized fungi to digest cellulose. Both worker and soldier termites cause harm to non-seasoned commercial wood and its formed materials. Whether it is a rural area or an urban domestic site, termite menace is everywhere. Members of this family construct great mounds having mean heights up to 5 m. The presence of these huge mounds in forests has ethnological value as these are used as burying places for dead bodies. Termites regulate the climate conditions within their nests. They built mounds with galleries and chamber. They make holes in mounds east-west face to keep the internal temperature cool and within the requirement of the colony. *Cephalotes oculatus* make mushroom-shaped mounds for their role in thermal regulation within the nest.[1]

Although, several methods have been used to control this termite species in field, the present article explains most recent developments happened in termite control. In the past, for the control of termite population in the field, various synthetic pesticides such as chlordane and cypermethrin,[2] hydroquinone and indoxacarb have been used.[3] For the

Address for correspondence:
Dr. Ravi Kant Upadhyay, Department of Zoology, Deen Dayal Upadhyaya Gorakhpur University, Gorakhpur, Uttar Pradesh, India. E-mail: rkupadhya@yahoo.com

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control of Formosan subterranean termite, *Coptotermes formosanus* Shiraki (*Isoptera*: *Rhinotermitidae*), phenylpyrazoles, pyrethroids, chloronicotinyls, and pyrroles are being used as termite control agents. Fipronil is termiticide belongs to phenyl-pyrazole class of chemical compounds. Although it effectively kills termites and other household insects vary efficiently,[4] it remains inside soil in the form of bound residues for longer period.[5] It is highly toxic to mammals and seeps inside the ground water.[6] These synthetic pesticides are highly toxic and present for longer periods in the form of residues in medium. They enter into the food chain and kill non-target organisms. These have been banned and its new alternatives are discovered in the form of natural pesticides.

In nature, both plants and animals possess natural bio-organic constituents which are synthesized in response to environmental conditions. This chemotypic information is acquired by the genome at a very slow rate and finally displayed as adaptability. These bioactive constituents found in plants show chemotypic variations and are used to control insect infestation and are good alternatives of synthetic pesticides or could be used as alternative medicines.[7] Natural products from plant were also found effective, environmentally friendly termite control agents.[8] This article also suggests wider use of natural eco-friendly multicomponent anti-termite formulations low-cost methods to control termite population and replace highly toxic synthetic pesticides.

SOURCE OF INFORMATION

For writing this comprehensive research review on plant essential oils (EOs), various databases were searched. For the collection of relevant information, specific terms such as phytochemical subject headings (PhytoSH) and key text words, such as "Family Rutaceae," "plant EOs," and "insecticidal activity" published till 2022 were used in MEDLINE. Most specially for retrieving all articles pertaining to the use of plant EOs, electronic bibliographic databases were searched, and abstracts of published studies with relevant information on the plant EOs were collected. Furthermore, additional references were included through searching the references cited by the studies done on the present topic. Relevant terms were used individually and in combination to ensure an extensive literature search. For updating the information about a subject and incorporation of recent knowledge, relevant research articles, books, conferences proceedings, and public health organization survey reports were selected and collated based on the broader objective of the review. This was achieved by searching databases, including "SCOPUS, Web of Science, EMBASE, PubMed, PMC, Publon, Swiss-Prot, and Google searches." From this common methodology, discoveries and findings were identified and summarized in this final review.

PLANT SPECIES BELONGS TO FAMILY RUTACEAE

Family Rutaceae is famous for *Citrus* fruits. Its leaves, flowers, and fruit peels contain EOs. These were traditionally used in folk medicine for thousands of years to treat a wide range of different diseases.[9] *Citrus* EOs (CEOs) consist of some major biologically active compounds such as α/β-pinene, sabinene, β-myrcene, d-limonene, linalool, α-humulene, and α-terpineol belonging to the monoterpenes, monoterpene aldehyde/alcohol, and sesquiterpenes group, respectively. These compounds possess several health benefits and are used for the treatment of pain, fever, nausea, inflammation, infections, and nervous disorders.[10] Few EO components are used as anti-fertility agents, to control menstrual flux and bleedings, as abortifacient, and as contraceptive. In addition, CEO are used in making perfumes, its essence is added to food materials, and beverage industries. EOs are used in aromatherapy and medicinal purposes. This reviews anti-insect potential of sweet orange (*Citrus sinensis*), bitter orange (*Citrus aurantium*), neroli (*C. aurantium*), orange petitgrain (*C. aurantium*), mandarin (*Citrus reticulata*), lemon (*Citrus limon*), lime (*Citrus aurantifolia*), grapefruit (*Citrus* × *paradisi*), bergamot (*Citrus bergamia*), Yuzu (*Citrus junos*), and kumquat (*Citrus japonica*).[11]

EOs and their components from various plant species show termiticidal activity against termites. *C. aurantifolia* leaves and fruit peel contain limonene, linalool, citronellal, and citronellol. These effectively repel insects and found effective against termites.[12,13] These EOs are highly volatile at a very low temperature and could be used as fumigants to control household termite population mainly reside inside tunnels, crevices, wood spaces, and holes. EOs are lipophilic secondary metabolites obtained from plants. These are obtained in pure form or a complex mixture of several components without making any change in their chemical composition.[14] Due to high volatility, EOs easily spread in the environment and medium. Due to their fast diffusion and volatile action, these could be used as fumigants to control household termite population mainly reside inside tunnels, crevices, wood spaces, and holes. These volatile EOs could be used as bio-insecticides in the control of different insect pests.

Citrus fruits secrete epicuticular waxes and EOs. These show anti-termite activity against the termite *Cryptotermes brevis* Walker (*Isoptera*: *Kalotermitidae*). It also shows strong antifeedant activity.[15] Vetiver oil and its components nootkatone and cedrene disrupt food recruitment in *C. formosanus* Shiraki.[16] Similar antifeedant activity has been reported in EO at very low dose (250–700 ppm) of *Alpinia galanga* due to the presence of 1,8-cineolagainst two species of termites, *Coptotermes gestroi* (Wasmann) and *Coptotermes curvignathus* (Holmgren) (*Isoptera*: *Rhinotermitidae*). Patchouli oil obtained from *Pogostemon cablin* (Blanco) Benth and its main constituent, patchouli alcohol. This oil shows strong repellency and toxicity against *Formosan* subterranean termites (*C. formosanus* Shiraki).[16] *Abrotanella trilobata* EOs and its constituents, especially the limonene, show repellent and termiticidal activity against *Nasutitermes corniger*. This oil also shows repellent action and deterrent activity from feeding.[17]

EO COMPONENTS

The *Citrus* fruit is rich in d-limonene, a cyclic terpene. It shows multiple biological activity against termites and other household insects.[18] The EO isolated of leaves and peel of Zambetakis (*C. limon*) contains limonene as major component. More specifically, leaf oil from pink-fleshed lemon (*Citrus x limon*), *C. limon* (lemon) contain beta-pinene, myrcene, neral, geranial, neryl acetate, geranyl acetate, and beta-caryophyllene.[19,20] These contain highly active bio-organic components, that is, monoterpene hydrocarbons, oxygenated monoterpenes, sesquiterpenes, and fatty alcohol esters.[21,22] Bergamot peel EO contains flavonoids which are also effective against microbes[23] [Figure 1].

EOS AND TERMITE CONTROL

Plant species synthesize thousands of active biomolecules and so many of them have been extracted and identified but its biological activities are still unknown.[24] Plant-derived compounds are used as an alternative of synthetic pesticides for termite control. Phytomelatonin (plant melatonin) is chemically related to the amino acid tryptophan and has many diverse properties. It shows actions at the cellular and physiological level, mainly display protective effects.[25] Plant secondary metabolites including alkaloids, flavonoids, and phenolics are very useful to control insects, pests, and pathogens in eco-friendly ways.[26] These are used as medicine ingredients and food additives for therapeutic, aromatic, and culinary purposes.

Flavonoids are widely distributed as secondary metabolites produced by plants and have a variety of potential biological benefits such as antioxidant, anti-inflammatory, anticancer, antibacterial, antifungal, and antiviral activity.[27] These secondary metabolites also work as deterrent of natural enemies of plants and also make defense against pathogens, environmental stresses.[28] Flavonoids are secondary metabolites, these showed antifeedant and repellent activity against *C. formosanus*.[29] Similarly, leaf of *Rhazya stricta Decne* and *Lantana camara* showed antifeedant activity against *Psammotermes hybostoma*[30] while *Callitris glaucophylla* against *C. formosanus*.[31] Seeds of *Withania somnifera*, *Croton tiglium,* and *Hygrophilia auriculata* disrupt cellulose digestion inside gut of *Microtermes obesi*[32] while seed oil of *Azadirachta indica* shows 100% mortality against *Macrotermes* spp.[32] Plant EOs and its components inhibit metabolism in termites and kill them due to antifeedant, repellent, and toxic action. Plant essential showed least residual effect in non-target organisms.

Plants produce a variety of useful bioactive products or a huge chemical diversity, these bio-organic compounds are used to control specialized natural enemies.[33] Phenolics play an essential role in the defense reaction of crop plants against pathogens.[34] Terpenoids (isoprenoids) chemical interactions affect feeding behavior in termites. Conventionally, plant-based terpenoids are used in food materials, pharmaceuticals, as bio-insecticides and biofuel products.[35] Limonoids are a group of highly oxygenated terpenoid secondary metabolites found mostly in the seeds, fruits, and peel tissues of *Citrus* fruits such as lemons, limes, oranges, pumellos, grapefruits, bergamots, and mandarins. Limonin, the aglycones, and glycosides of limonoids show insecticidal activity.[36] Organic extracts of *Flourensia* species contain sesquiterpenes, flavonoids, benzofurans, chromenes, coumarins, lupantriterpenes, aliphatic lactones, and aromatic and acetilenic compounds. The chemical components of tarbush (*Flourensia cernua*) leaves were fractionated by extracting successively with hexanes, diethyl ether, and ethanol. All three fractions exhibited a high degree of anti-termite activity.[37] *Citrus* fruits mainly contain lemon, mandarin, and sweet orange EOs showed a promising potential against termite and other harmful microbes.[38]

EOs and its components from peel were found highly active against insect and household insect pests. These showed repellent and toxic effects in termites. *C. sinensis* peel EO components inhibit acetylcholinesterase (AChE), Na^+/K^+-ATPase, and glutathione-S-transferase activity in insects and could be used to develop a potential botanical pesticide.[39] Similarly, EOs and its components from *Cinnamomum cassia*, *Cinnamomum camphora, Cinnamomum camphora* var. linalooliferum, *C. aurantium, C. aurantium* var. bergamia, *C. aurantifolia,* and *C. reticulata* var. tangerine show acaricidal activity against mites.[40] EO from the peel of *C. aurantifolia* showed ovicidal and larvicidal activity in *Aedes aegypti*.[41] EO from the fruits of *Citrus trifoliata* L. showed high insecticidal activity against field termites.[42]

Development of natural nano-based plant protection formulations represents an emerging phenomenon that has been widely improved for crops protection and for enhancing the efficiency and safety of pesticides. *C. aurantium* EOs derived from flavedo of cultivars "Canaliculata," "Consolei," "Crispifolia," "Fasciata," "Foetifera," "Listata," and "Bizzaria" possess diverse phytochemicals. These showed antioxidant, antifungal, and insecticidal activity.[43] Pompia peel EO also contains variety of phytochemicals which showed different types of insecticidal activity.[44]

Similarly, several other plant species, that is, *Zizyphus jujuba* showed significant anti-termite activity against *Heterotermes indicola*. *Flourensia* species exhibit insecticidal mainly anti-termite activities.[45] Plant extracts from *Pyllanthus*

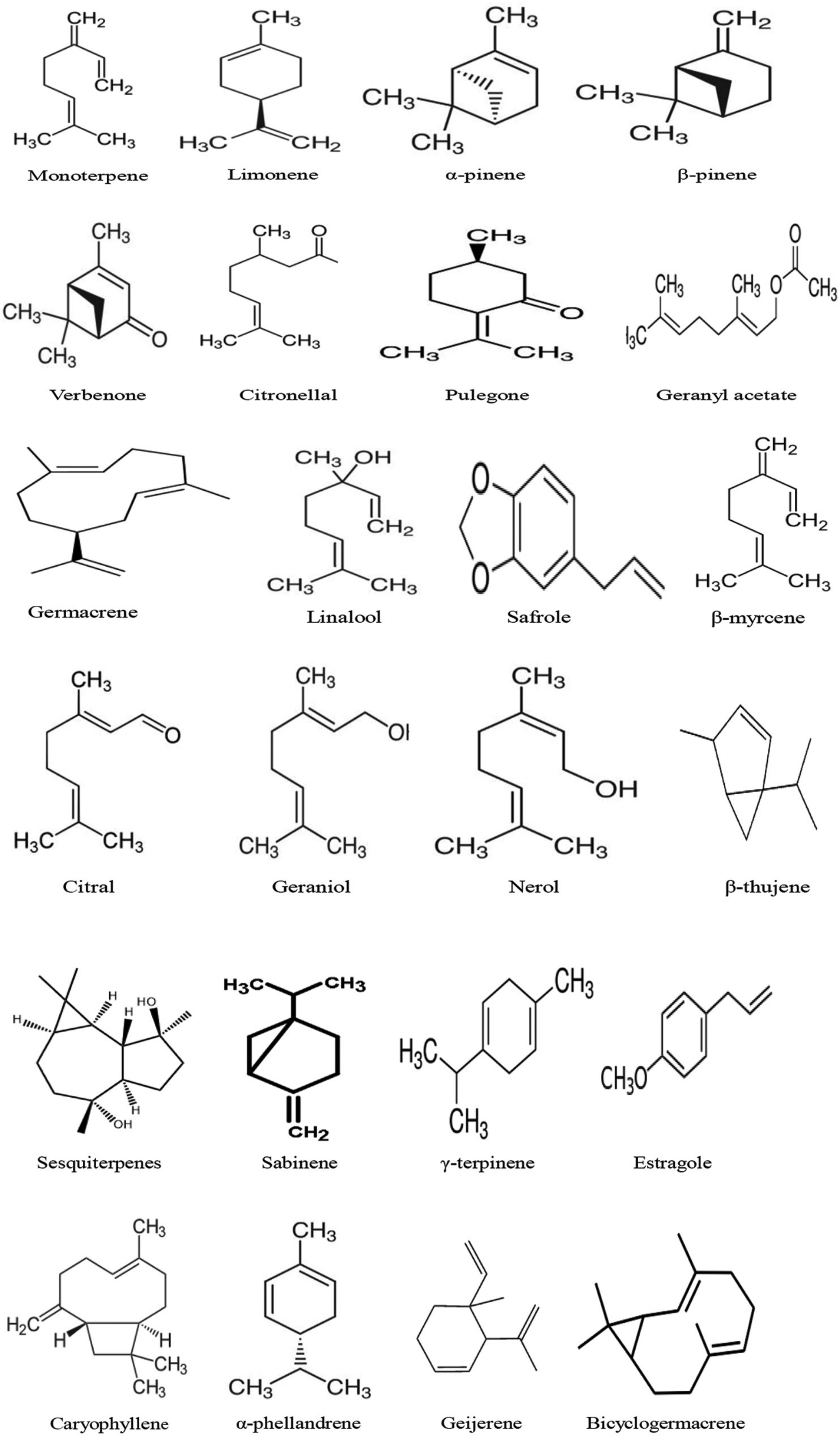

Figure 1: Chemical structures of major essential oil components from family Rutaceae

niruri, *Azadirachta indica*, *Leucaena leucocephala,* and *Andrographis paniculata* inhibited tunneling behavior in two subterranean termites, *Globitermes sulphurues* and *C. gestroi.*[46] EO constituents from various *Citrus* species contain β-thujene, β-pinene, γ-terpinene, myrcene, and sesquiterpenes which showed termiticidal effects.[47] Similar property is also reported in bio-organic active compounds such as linalool and linalyl acetate from *Ocimum basilicum*; α-terpinyl acetate, neryl acetate, and α-pinene from *Thymus algeriensis*; thymol, 1,8-cineole, umbellulone, α-bisabolol, and camphor from *Tanacetum walteri;*[48] sesquiterpenes, β-eudesmene, and β-bisabolene from *Helichrysum italicum;*[49] eugenol from *Syzygium aromaticum*;[50] and carvacrol, thymol, eugenol, and cinnamaldehyde from *Eugenia caryophyllata* showed multiple biological activity including termiticidal effects in major of them[51] [Figure 1].

Eucalyptus camaldulensis major oil component 1,8-cineole, α-pinene, α-phellandrene, p-cymene, and anti-acetyl-cholinesterase;[52] alpha-pinene, 4-carene α-cedrol, terpinolene, β-myrcene, β-pinene, sabinene, and D-Limonene from *Thuja occidentalis* antimicrobial; and caryophyllene oxide, p-caryophyllene, and spathulenol isolated from *Tagetes patula* showed deterrent effects.[53] Components such as α-pinene, verbenone, terpinolene, and α-terpineol isolated from *Helianthus annuus;*,[54] neophytadiene, phytol, trans-pinane, 6,10,14-trimethyl-2- pentadecanone, and citronellyl propanoate isolated from *Jatropha curcas* show antioxidant and anti-inflammatory activity.[55] Menthol, menthofuran, menthyl acetate, menthone, and 1,8-cineole found in *Mentha piperita* showed insecticidal activity. [56] Cinnamaldehyde, linalool, β-caryophyllene, eucalyptol and eugenol extracted from *Cinnamomum zeylanicum* have shown strong anti-insect potential [57] Similar insecticidal activity is also reported in *Ricinus communis* due to presence of α-thujone, 1,8-cineole, α-pinene, camphor and camphene [58] [Table 1 and Figure 1].

EOs isolated from various species of *Citrus* possess highly effective bio-organic constituents such as monoterpene, limonene, β-pinene, geranyl acetate, and verbenone from *Citrus maxima*;[59] citronellal and citronellol from *Citrus grandis*;[60] germacrene isomers, pinene, linalool dimmer, bornane, citral, anethole, anisole, safrole, and demitol from *C. aurantifolia*;[61] and limonene, β-myrcene, and α-pinene from *C. aurantium*[62] [Table 1]. Few important constituents such as d-limonene, linalool, geraniol, nerol, monoterpene aldehydes, alpha- and beta-pinene, myrcene, sesquiterpenes in most of the *Citrus* plant species;[63,64] alpha-terpinene, alpha-pinene, and sesquiterpene have been isolated from *Citrus paradise*[65] and *Citrus latifolia*.[66] *Agathosma betulina*[67] from *C. limon*[68] germacrene and hexane from *C. japonica*[69] and sabinene from Citrus *hystrix* are anti-termite in nature [Table 1].

The EO fraction obtained from the rind various *Citrus* species possess diverse volatile organic. The major compounds reported are terpenoid (90%) with diverse biological activity.[70] *Aegle marmelos* also contains limonene, α-phellandrene, β-ocimene, α-pinene, (E)-caryophyllene, β-elemene, and germacrene;[71] sesquiterpene hydrocarbons, germacrene D, and (E)-caryophyllene from *Casimiroa edulis*;[72] E-ocimenone, Z-ocimenone, gamma-terpinene, and germacrene D from *Clausena anisata*;[73] 2-tridecanone, beta-caryophyllene, 2-pentadecanone, caryophyllene oxide, and germacrene D from *Pilocarpus microphyllus*.[74] Limonene from *Pilocarpus spicatus*;[75] β-myrcene, (Z)-β-guaiene, (Z)-β-ocimene, β-caryophyllene, bicyclogermacrene, α-terpinyl acetate, geijerene, and β-copaene-4α-ol from *Boenninghausenia albiflora*;[76] dictagymnin and feniculin estragole from *Dictamnus albus*;[77] *Agathosma betulina* limonene, pulegone, α-pinene, β-pinene, p-cymene, and linalool act as feeding deterrent in termites.

THERAPEUTIC USES

The family Rutaceae is famous for its EOs which are used for making perfumes. *Citrus* fruits are highly edible, its juice is used to beat heat stress. *Citrus* genus is the most important fruit tree crop in the world and lemon is the third most important *Citrus* species. *C. limon* EO generates unique flavor in food or nutraceutical products.[78] EOs extracted from the peels of four *Citrus* fruits (*C. limon*, *C. aurantifolia*, *Citrus maxima,* and *C. sinensis*) have much more antimicrobial potential mainly against fungal strains.[79] Tangerine (*Citrus tangerina*) EOs are widely used as aromatherapy and medicinal agents.[80] Inhalation of the EO from *C. aurantium* decreases anxiety and stress levels in patients undergoing coronary angiography.[81] EOs from this plant contain monoterpenes linalyl acetate, limonene, and α-terpineol as major compound which possess high therapeutic value.[82] These also showed diverse biological activities.[83] The EO and ethanol extract showed significant antimicrobial activity against various pathogens which were attributed to the presence of important phytochemical classes such as polyphenols, flavonoids, alkaloids, and terpenes.[84] *Citrus* fruit EOs show good antimicrobial and antioxidant properties.[85] *Citrus* peel EOs work as natural preservative and antioxidants[13] [Table 1].

EOs from Rutaceae are traditionally used in folk medicine. The EO from *C. limon* is rich in bioactive monoterpenoids such as D-limonene, β-pinene, and γ-terpinene; these show anti-inflammatory, antimicrobial, anticancer, and antiparasitic activities[21] [Table 1]. The major phytochemicals in EO are phenolic compounds (diosmin, hesperidin, and limocitrin), coumarins and flavonoids, and phenolic acids. These have shown broad pharmacological activities, such as antifungal, antiviral, antiparasitic, antioxidant, neuroprotective, anti-inflammatory, anti-cancer, and antidiabetic activities. EOs also display contraceptive and abortifacient effects.

Peel of *Citrus* fruits contains large numbers of plant secondary metabolites which display chemotypic variations in limonene; limonene/gamma-terpinene;

Table 1: Major essential oil components isolated from family Rutaceae plants and its termiticidal action

S. No.	Name of plants	Common Name	Essential oils major components	Activity against termite species	References
1.	*Citrus maxima*	Pomelo	Monoterpene, limonene, β-pinene, geranyl acetate, verbenone	*Coptotermes gestroi*	[59]
2.	*Citrus grandis*	Pomelo	Citronellal and citronellol	*Coptotermes formosanus*	[60]
3.	*Citrus aurantifolia*	Kagzi lime	Germacrene isomers, Pineen, Linalool dimmer, Bornane, Citral, Anethole, Anisole, Safrole, Demitol	*Reticulitermes flavipes*	[61]
4.	*Citrus aurantium*	Bitter orange	Limonene, β-myrcene, α-pinene	*Coptotermes formosanus*	[62]
5.	*Citrus sinensis*	Sweet orange	d-limonene, Linalool, Geraniol, Nerol	*Coptotermes gestroi*	[63]
6.	*Citrus microcarpa*	Calamansi	Limonene	*Reticulitermes speratus*	[64]
7.	*Citrus medica*	Citron	Limonene, gamma-terpinene, monoterpene aldehydes, alpha- and beta-pinene, myrcene, sesquiterpenes	*Odontotermes obesus*	[47,63,64]
8.	*Citrus paradisi*	Grapefruit	limonene, alpha-terpinene, alpha-pinene, Sesquiterpene	*Coptotermes vastator*	[65]
9.	*Citrus latifolia*	Persian lime	d-limonene, β-thujene, β-pinene, γ-terpinene	*Coptotermes curvignathus*	[66]
10.	*Citrus limon*	Lemon	Geranial, limonene, γ-terpinene	*Reticulitermes speratus*	[68]
11.	*Citrus japonica*	Round kumquat	Limonene, germacrene, hexane	*Coptotermes formosanus*	[69]
12.	*Citrus hystrix*	*Kaffir lime*	Sabinene	*Coptotermes formosanus*	[64]
13.	*Aegle marmelos*	Stone apple/bael	Limonene, α-phellandrene, β-ocimene, α-pinene, (E)-caryophyllene, β-elemene, germacrene	*Odontotermes obesus*	[71]
14.	*Casimiroa edulis*	White sapote	Sesquiterpene hydrocarbons, germacrene D, (E)-caryophyllene	*Cryptotermes brevis*	[72]
15.	*Clausena anisata*	Horsewood	E-ocimenone, Z-ocimenone, gamma-terpinene, germacrene D	*Coptotermes vastator*	[73]
16.	*Pilocarpus microphyllus*	Maranham jaborandi	2-tridecanone, beta-caryophyllene, 2-pentadecanone, caryophyllene oxide, germacrene D	*Coptotermes curvignathus*	[74]
17.	*Pilocarpus spicatus*	Jaborandi	Limonene	*Coptotermes formosanus*	[75]
18.	*Boenninghausenia albiflora*	Pissumar	β-myrcene, (Z)-β-guaiene, (Z)-β-ocimene, β-caryophyllene, bicyclogermacrene, α-terpinyl acetate, geijerene and β-copaene-4α-ol	*Reticulitermes flavipes*	[76]
19.	*Dictamnus albus*	Burning bush	Dictagymnin, Feniculin, Estragole	*Reticulitermes speratus*	[77]
20.	*Agathosma betulina*	Buchu	Limonene, pulegone, α-pinene, β-pinene, p-cymene, linalool	*Coptotermes vastator*	[67]

limonene/beta-pinene/gamma-terpinene; and limonene/gamma-terpinene/beta-pinene/oxygenated products.[86] EOs from peel are used as bio-insecticides in the control of different insect pests EOs of *A. marmelos*, *Murraya koenigii*, *C. reticulata* Blanco, *Zanthoxylum armatum*, *Skimmia laureola*, *Murraya paniculata*, and *B. albiflora*, showed insecticidal, toxicological, and medicinal properties[87] [Table 1].

Plant EOs possess multiple biological activities such as antibacterial, antifungal, anti-cancer, and antioxidant. These are used for a wide variety of purposes such as flavoring, perfuming[88] aromatherapy, and food preservation.[89] EOs are used in food flavoring and making soaps, lotions, shampoos, hair styling products, cologne, laundry detergents, and even insect repellents. EOs exhibit a large spectrum of biological activities *in vitro*. These are bactericidal agents and inhibit growth of drug-resistant pathogens.[90] These also show antioxidant, anti-inflammatory, anticancer, antibacterial, antifungal, antiviral activity,[27] insecticidal, and antioxidant properties.[91] *C. sinensis* natural products are also found beneficial for human health and used to develop new drugs.[92] Cannabis and cannabinoids isolated from *Cannabis sativa* or hemp shows several medicinal properties.[93] *C. reticulata* Blanco EOs generate cytotoxicity in *Penicillium italicum* and *Penicillium digitatum* by disrupting cell membrane integrity and causing the leakage of cell components[94] [Table 1]. Volatile components of *Citrus* fruit EOs show inhibitory action on *P. digitatum* and *P. italicum* growth.[95] Bergamot fruit peel EO (bergamot EO: BEO) is used to make perfumes, cosmetics, and confections. It is used in aromatherapy for reducing anxiety and stress.[96] *Citrus* EOs are valuable in the perfume, food, and beverage industries, and have also enjoyed using as aromatherapy and medicinal agents [Table 1].

CONCLUSION

Plants belong to family Rutaceae possess complex mixtures of EOs, its diverse chemical constituents such as lectins, polypeptides, alkaloids, phenols, quinines, flavones, flavonoids, terpenes, tannins, coumarins, benzene derivatives, various hydrocarbons, and straight chain compounds. These oil components showed broad-spectrum biological activity, that is, antibacterial, antifungal, antiviral, insecticidal, and antioxidant properties. As termites are polyophagous and highly destructive pests, various EO-based formulations could be synthesized. Plant EOs and its constituents can be used as antifeedant, repellent, and toxicants against field and household termites. These can be employed for cultural, behavioral, microbial, genetical, and biological for the control of termites to minimize the use of synthetic pesticides to save the ecological food chains from poisoning. No doubt these could be used as development of alternative treatments. These plant origin natural pesticides control wide range insect pests efficiently and cut down the pest population even applied in very low quantity. These plant origin pesticides inhibit metabolism in termites and are much safer, low cost, and easily biodegradable in the medium and show no residual effect. These potential anti-termite agents can be prepared at small scale by farmers to control termite menace.

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