ISSN (ONLINE) 2583-2506
http://publications.rayatbahrauniversity.edu.in
RBIJMR-Rayat Bahra International Journal of Multidisciplinary Research, Vol. 03, Issue 02, December 2023

Insecticidal Efficacy of Essential Oil Extracted from Therapeutic Plant

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Abstract: *This review article delves into the diverse and promising realm of essential oils as potent insecticidal agents. Spanning various plant sources, the comprehensive analysis encompasses the bioactive compounds within essential oils that exert insecticidal effects, elucidating their mechanisms of action. Essential oils, derived from plants, showcase a complex interplay of compounds such as terpenes, phenols, and aldehydes forming the basis of their insecticidal efficacy. Essential oils (Eos) or EO-based products are potentially promising assets for biocontrol agents due to their safe, bioactive, biodegradable, ecologically, and economically viable properties. The article highlights the efficacy of essential oils against a wide spectrum of insect pests and also addresses challenges such as volatility and stability while evaluating various application methods. Furthermore, the review critically examines the advantages, challenges, and future directions in harnessing essential oils for sustainable insect control strategies, emphasizing their eco-friendly nature and low environmental impact. Additionally, this review provides a valuable resource for researchers and practitioners, offering insights into the current state and proposes avenues for exploration, positioning essential oils as promising agents in the ongoing quest for environmentally friendly insecticides.*

Keywords: Eco-friendly insecticides, insecticidal efficiency,natural insecticides, medicinal plants, essential oil.

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1. Introduction

Since ancient times researchers have investigated and found different plant products beneficial for humans and environment. One such plant product is essential oil that exhibit activities such as Antimicrobial, Antifungal, Antifeedent, Anti-inflammatory, Insecticidal etc . Essential oils (often, referred as volatile oil or ethereal oil) are natural, aromatic, volatile, lipophilic substance that consist of multiple compounds synthesized as secondary metabolites in plants [1].

The earliest known uses of oils are from India, Persia, & Egypt. Greece and Rome also engaged within the broad exchange of aromatic oils and ointments with Eastern nations. The method of extricating oil through plant distillation at first created by middle easterns date, about 3000 essential oils has been unearthed but only 300 of them are utilized in various industries like pharmaceutical, agricultural, food, beverage, sanitary, cosmetics [2].

Chemically they are regarded as complex mixture of hydrocarbons and their oxygenated derivatives or highly concentrated non water based phytochemicals made up of organic compounds. They act as part of immune system that provides protection from predators and pests but simultaneously attracts pollinators too. The components of an essential oil, as well as the plant from which it is extracted, decide its name. These oils were given the name “essential”, because they are believed to capture a plants essence, that is its and flavor.

Plants either have external secretory structures (epidermal cells, glandular hairs, glandular trichomes), which are found on the surface of plant, or, internal secretory structures (secretory cavities, secretory cell, & secretory ducts), which are found in the plant materials where they store oils [3]. There are oils present in many different organs, but are more commonly found in flowers and leaves [4].They are found in superior plants belonging to order Angiosperms and Gymnosperms. Nonetheless, angiosperms are linked to the majority of significant commercially available essential oils [5]. Due to their diverse applications they have been known to mankind since past centuries.

2. Insecticidal activity of Essential oils

Scientists have conducted several experiments to derive essential oils from diverse species from different regions including *Azadirachta indica* (Neem), *Ocimum tenuiflorum* (Tulsi), *Syzygium aromaticum* (Clove), *Allium sativum* (Garlic), *Zingiber officinale* (Ginger), *Momordica charantia* (Bitter gourd), *Dendranthema grandiflora* (Chrysanthemum), and many more exhibiting insecticidal properties that are frequently used as insect repellent having ability to kill or repel insects. And this repellency activity is known to play an important role in preventing agricultural products from pests and vector borne diseases by reducing man-vector contact. Past studies focused on potential use of plant based Insecticides against diverse insect species. It has been reported that essential oils from oregano and Savory were highly effective against *Plodia interpunctella* (Indian meal moth) and *Ephestia kuchniella* (mill moth) due to carvacrol compound. Whereas Myrtle oil was having Insecticidal activity against *Aedes obtectus* [6]. Essential oils from leaves of *Coccinia grandis* exhibited significant larvicidal activity against *Aedes stephensi* with LC50 and LC90 values 39.41ppm and 123.24ppm, respectively. This was followed by *A. aegypti and C.quinquefasciatus* with LC50 and LC90 values of 48.20ppm, 131.84ppm and 52.80ppm, 135.48ppm, respectively after 24h of exposure [7].

Lemon grass oil is used as repellent against (*Helicoverpa armigera*) gram pod borer insect and 100% mortality rate was achieved on testing with lemon grass oil [8].Clove, Coriander, Neem and Mint oil exhibit repellency against red flour beetle that cause damage to storage grains and other crops [9].

Essential oils extracted from *Cinnamomum verum* leaf and flower showed insect repellent properties against two common pests named *Sitophilus oryzae* and *Callosobruchis maculatus* . These oils also showed larvicidal and antibacterial properties against pests [10]. Lemon grass and orange oil have possessed larvicidal, pupicidal and adulticide properties against *Musca domestica* [11].

Neem oil at 1.5% + 0.2% isopropyl alcohol was effective against papaya mealybug (*Paracoccus marginatus*) by 93.0% equivalent to the positive control (imidacloprid) (99.4%), followed by citrus oil at 1.5% + isopropyl alcohol (76.3%) and citrus oil at 1.5% + paraffin oil (68.8%), compared with the untreated 0.01%. Hence, neem oil was found to be more effective followed by citrus and garlic [12].Essential oils extracted from medicinal herbs were significantly more toxic

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to the larvae and pupae of *Culex quinquefasciatus, Anopheles stephensi*, and *Aedes aegypti* with LC50 = 9.23, 12.85, and 14.46 ppm, as well with 10.22, 11.39, and 12.81 ppm, with oviposition active indexes of −0.84, −0.95, and −0.92, respectively [13].

Although the biodiversity of the Kangra Valley is well known, little is known about the insecticidal potential of essential oils derived from the Harchakian region. Hence, this study is designed to explores the potential of essential oils extracted from selected plant source as natural Insecticides. Essential oil will be extracted and subjected to rigorous chemical analyses to comprehend their compositions. Bioassays will be conducted to investigate the insecticidal efficacy of essential oil against specific target vector. The findings shall contribute to the development of eco-friendly insect management strategies, fostering a harmonious balance between effective insects control and environmental sustainability [14].

3. Methods employed in extracting Essential oils

The extraction of essential oils involves various methods, each tailored to the specific characteristics of the plant material. Water distillation, water and steam distillation, steam distillation, cohobation, maceration and enfleurage are the most traditional and commonly used methods [15]. During hydrodistillation, aromatic plant material is placed in a still, and an ample amount of water is added and brought to a boil. Alternatively, live steam is introduced into the plant charge. The heat from the water and steam prompts the release of essential oil from oil glands within the plant tissue. The resulting vapor mixture of water and oil undergoes condensation through indirect cooling with water. The condensed distillate then moves into a separator, where the essential oil automatically separates from the distilled water. Three are three types of hydrodistillation for isolating essential oils from plant materials: Water distillation, Water and steam distillation and Direct steam distillation [16].

Another method, cold pressing, any physical process that is employed for citrus fruits, mechanically squeezing the oil-containing glands. Solvent extraction utilizes chemical solvents to dissolve essential oils, a process often employed for delicate flowers. Enfleurage, a traditional method, involves placing plant material in odorless fats to absorb essential oils [15]. CO_2 extraction employs carbon dioxide under high pressure, yielding high-quality oils. Each method preserves distinct aromatic compounds, contributing to the diverse world of essential oils.

With the advancement in technology new methods have been developed to produce essential oils commercially on large scale.These techniques include Solid phase micro-extraction ,Supercritical fluid extraction [17], Phytosol (phytol) extraction, Protoplast technique, Microwave assisted hydrodistillation [18], Controlled instantaneous decomposition, Thermomicrodistillation, Microdistillation and Molecular spinning band distillation [15].

4. Compounds imparting insecticidal activity to Essential oils

Essential oils are intricate blends of different bioactive compounds including Terpenes (monoterpene, diterpenes, sesquiterpene)phenols , aldehydes, alcohols, esters, ketones , and phenylpyropanoids that have robust antimicrobial and functional properties [19]. The chemical composition of essential oils is lipophilic which can enter into insect and cause biochemical dysfunction and mortality [20].Terpenes are the primary constituent of essential oils ,which are concentrated liquid extracts with a lot of complexity. Due to the presence of hundred of aromatic molecules in different combinations essential oils get their properties and characteristic odor. The presence of diverse chemical compounds impart them attributes like Aromaticity, Volatility, Concentrated, Antimicrobial, Antioxidant, Anti-inflammatory, Insecticidal, Therapeutics, Antifeedent, Repellent, Fungicidal etc.

Essential oils exhibit insecticidal properties due to specific chemical constituents. Some key compounds include:

- Monoterpenes: These are the most common constituents and include compounds like limonene, pinene, and myrcene. Monoterpenes often contribute to the characteristic fragrance of essential oils. Limonene and pinene disrupt insect nervous systems, acting as natural repellents.
- Sesquiterpenes: Larger and more complex than monoterpenes, sesquiterpenes include compounds like caryophyllene and farnesene. They contribute to the therapeutic properties of some essential

oils. Cedrene and beta-caryophyllene contribute to insecticidal properties.

- Phenols: Compounds such as thymol, eugenol and carvacrol have strong antimicrobial properties. Phenols can have significant insecticidal and antifungal effects.
- Aldehydes: Compounds like citronellal and citral are common aldehydes in essential oils. They contribute to the aroma and may have insect-repellent properties.
- Ketones: Examples include Menthol and camphor that act as contact insecticides or repellents. Ketones can have stimulating or soothing effects, depending on their concentrations and specific oils.
- Esters: Esters, like linalyl acetate and bornyl acetate, contribute to the floral and fruity notes in some essential oils. They often have calming or sedative properties.
- Oxides: Oxides, such as cineole, have expectorant and respiratory benefits. They may contribute to insecticidal effects as well.
- Alcohols: Compounds like geraniol and linalool are common alcohols in essential oils. They contribute to the pleasant scent and may have antimicrobial properties.
- Terpenoids: A broad category that includes monoterpenes and sesquiterpenes. Terpenoids often have diverse biological activities, including insecticidal properties.

The synergistic effects of these compounds create a potent natural insecticidal action, making essential oils attractive alternatives to synthetic pesticides with fewer environmental concerns.

5. Mechanism of action of essential oils as Insecticides

Some reports suggest that oils with insecticidal activities can be inhaled, ingested, or skin absorbed by insects [21]. Essential oils are thought to disrupt basic biochemical, physiological, behavioural and metabolic functions of insects. However, not much is understood regarding their complete mode of action [22].The mono- and sesquiterpenoid are considered to be fast action neurotoxins in insects and related Arthropods [23]. Moreover some significant sublethal behavioural effects including larvicidal, ovicidal, pupicidal, antifeedent, effects are exhibited by these compounds [22]. Some key concepts regarding mechanism by which Eos work is summarised below:

1. Neurotoxicity: Essential oils often contain compounds that affect the nervous system of insects either by Inhibition of acetylcholinesterase (AChE) or by blocking the octopamine receptors [24]. For instance, terpenoids found in many essential oils can disrupt neurotransmitter function, leading to neurotoxic effects. This interference with the insect's neural pathways can result in paralysis or death.
2. Respiratory Disturbance: Some essential oils impact the respiratory systems of insects. Compounds such as menthol or eugenol can interfere with the normal functioning of insect respiratory organs, causing respiratory distress and ultimately leading to the death of the insect.
3. Cellular Disruption: Certain essential oil components may disrupt cell membranes, affecting the integrity of cells in the insect's body. This disruption can lead to cell leakage, dehydration, and, ultimately, the death of the insect.
4. Repellency: Essential oils often exhibit repellent properties, deterring insects from approaching treated areas. This can disrupt their feeding habits, mating behaviors, and overall life cycle. The volatile nature of essential oils contributes to their ability to create a protective barrier against insects. Essential oils of neem, lemon grass, eucalyptus, lavender, citronella are known for their repellent effects.
5. Oxidative Stress: Essential oils can induce oxidative stress in insects by generating reactive oxygen species (ROS). Increased oxidative stress can damage cellular structures, including proteins, lipids, and DNA, leading to cell dysfunction and death.
6. Disruption of Cell Membranes: Some essential oil components can disrupt the integrity of insect cell membranes. This disruption can lead to cell leakage, loss of ions, and cell death. Terpenoids, for example, may have membrane-disrupting effects.
7. Inhibition of Enzymes: Essential oils may interfere with essential enzymatic processes in insects. This can affect metabolic pathways, leading to energy depletion, disrupted digestion, and other metabolic imbalances. Terpenoids and phenolic compounds in essential oils are known to interact with enzymes.
8. Antifeedant Effects: Essential oils may act as feeding deterrents, making plants or surfaces treated with them less appealing to insects. Essential oils contain compounds that can interfere with the

feeding behavior of insects, acting as repellents. For example, two essential oils, Jojoba and Cyperus, showed insecticidal and antifeedent activity against the adults of the rice weevil Sitophilus oryzae [25]. This property is valuable in pest control, as it can help protect crops or stored products from damage. The specific mechanisms can vary, but essential oils often disrupt the insect's sensory perception, making the plant less appealing as a food source.

It's important to note that the effectiveness of essential oils as insecticides can vary based on factors such as the specific composition of the oil, concentration used, and the target insect species and many other as follows [26]:

- Chemical Composition: The specific compounds present in essential oils play a crucial role. Different compounds may target specific physiological processes in insects. The concentration and ratio of these compounds contribute to the overall effectiveness
- Insect Species: The susceptibility of insect species varies. Essential oils may be more effective against certain insects while showing limited efficacy against others. Targeting specific pests requires understanding their biology and vulnerabilities.
- Application Method: The method of application, whether through direct contact, fumigation, or residual application, can impact effectiveness. The formulation and delivery system, such as sprays, vaporizers, or impregnated materials, also influence distribution and persistence.
- Concentration: The concentration of essential oils in the formulation affects their potency. Higher concentrations may have stronger insecticidal effects but could also impact safety and environmental considerations.
- Environmental Conditions: Factors like temperature, humidity, and light can influence the stability and volatility of essential oils. Some essential oils may degrade or evaporate rapidly under certain conditions, affecting their longevity and efficacy [27].
- Persistence: The duration of insecticidal activity varies among essential oils. Some may provide short-term effects, requiring frequent reapplication, while others exhibit longer persistence. The choice of essential

oil should align with the desired duration of control.

- Synergistic Effects: Combining essential oils or using them in combination with other insecticides can result in synergistic effects, enhancing overall efficacy. This approach may also reduce the risk of resistance development.
- Application Timing: Timing of application in the insect's life cycle is crucial. Some essential oils may be more effective during specific developmental stages, such as eggs, larvae, or adults. Understanding the life cycle of the target pest is essential for optimal results.
- Environmental Impact: Considerations for environmental impact, including non-target organism safety and ecological effects, are essential. Essential oils are often regarded as more environmentally friendly, but their impact on beneficial insects and ecosystems should be assessed.

Understanding and optimizing these factors are crucial for the successful use of essential oils as insecticides, providing effective pest control while minimizing adverse effects on the environment and non-target organisms.

6. Benefits and Drawbacks of Essential oils as Insecticides

According to [28], [29] and [30] there are numerous benefits of utilizing essential oils as insecticides including their natural origin, negligible natural impact, and viability against certain pests. Unlike synthetic insecticides, essential oils are biodegradable and may pose fewer risks to humans, animals, and beneficial insects . Additionally, they often have pleasant aromas, making them a more appealing option for those seeking natural alternatives to chemical pest control. Eos have repellent, insecticidal, and growth-reducing effects on a variety of insects. They have been used effectively to control preharvest and postharvest phytophagous insects and as insect repellents for biting flies and for domestic and garden insects [31].

While essential oils are considered natural insecticides, they have limitations like inconstancy in viability among diverse oils, potential skin irritation or hypersensitivities in humans, and their often pleasant aroma may dissipate quickly, influencing long-term repellent properties. The volatile nature of essential oils makes them prone to rapid evaporation and photodegradation when exposed to sunlight. This limits their persistence in the environment and may require frequent reapplication [32].Furthermore, essential oils may not provide comprehensive control against all types of pests, and their cost can be higher compared to synthetic alternatives. Integration into large-scale agribusiness too postures logistical challenges. Essential oils can be sensitive to environmental conditions such as temperature and humidity. These factors may affect the stability and performance of the oils, impacting their reliability as insecticides [26].

7. Strategies for overcoming barriers in harnessing essential oils

To upgrade the effectiveness of essential oils as insecticides one can invest into research and development to improve stability, reduce volatility, and persistence by incorporating essential oils into new formulations like Encapsulation, microemulsion or nanoemulsions [33]. These include liposomes, polymer-based nanocarriers, lipid-based nanocarriers and molecular complexes. It is believed that nanoencapsulation of essential oils will improve their therapeutic activity and delivery [34]. It was reported that the insecticidal activity basil oil against *Aedes aegypti* was increased in nanoemulsion formulation. The nanoemulsion containing basil oil, Tween 20 and water was formulated with droplet size of 30 nm ultrasonic emulsification method that demonstrated dose and time dependent killing of mosquito larva [35]. Another strategy of synergistic combination can include mixing different essential oils with complementary properties to create a more potent insecticide. For example, mixtures of the essential oil of *Dysphania ambrosioides* and the essential oils of *Piper graveolens*, *P. tuberculatum*, *P. gaudichaudianum*, *P. diospyrifolium*, and *P. arboreum* were extremely toxic to *Sitophilus zeamais*. The mixtures were more toxic than all the oils applied individually, which demonstrated a synergistic action that provide a broader spectrum of repellent and insecticidal effects [36]. Diluting essential oils in carrier oils like coconut or olive oil can increase their stability and improve adherence to surfaces. This can enhance the residual effect and prolong the efficacy of the insecticidal solution. Along with innovative delivery system such as bio based carriers effectiveness of essential oils can be increased by rotation of different essential oils that helps insects in from developing resistance.

8. Conclusion

In conclusion, the insecticidal properties of essential oils present a promising avenue for environmentally friendly pest control. While they offer natural and safer alternatives, acknowledging their limitations, such as variable efficacy and shorter durations, is crucial. Continued research and development are needed to enhance their potency, broaden the spectrum of targeted pests, and optimize application methods. The integration of essential oils into broader pest management strategies, combined with advancements in technology, offers a promising pathway for developing effective, natural, and sustainable solutions to address the challenges of pest control in the future.

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