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Insecticidal Activity of *Litsea cubeba* Essential Oil: A Short Review

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ABSTRACT

Rising demand for environmentally friendly alternatives to synthetic pesticides has spurred research into plant-derived essential oils with insecticidal properties. Among these, *Litsea cubeba* (Lour.) Pers. has attracted considerable attention for its high levels of bioactive terpenoids, particularly citral, limonene, and pinene derivatives. This review summarizes the chemical composition, biological properties, and insecticidal activities of *L. cubeba* essential oil against various agricultural and stored-product pests. Studies have demonstrated significant fumigant, contact toxic, repellent, and acaricidal activities against insects such as *Lasioderma serricorne*, *Liposcelis bostrychophila*, *Tenebrio molitor*, and *Trichoplusia ni*. The review also discusses potential mechanisms of action, advantages over conventional pesticides, and prospects for commercialization. Current evidence suggests that *L. cubeba* essential oil is a promising botanical insecticide that may contribute to sustainable pest management.

KEYWORDS: *Litsea cubeba*; Essential oil; Botanical insecticide; Citral; Pest management; Insecticidal activity

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1. INTRODUCTION

Of late, there has been a high increase in the desire and use of natural/organic substances in place of synthetic/inorganic/artificial ones. This trend is growing at a high/very fast rate (Diaz-Sanchez et al., 2015). This trend might be a result of health-impacting challenges occurring from the use of artificial chemical substances.

Essential oil, also referred to as volatile oil, is a highly volatile, odorous liquid extracted from aromatic plants, with the composition varying by plant source. Essential oils have varying medicinal values/benefits, such as energizing and soothing. The phytochemical (phytonutrient) present in the plant source determines the kind of effect displayed. Some essential oils include rose, peppermint, lavender, etc. (Koul et al., 2008). Although essential oils have broad applications in aromatherapy, cosmetics, and food preservation, this review focuses specifically on their insecticidal properties.

Litsea cubeba, commonly known as Chinese pepper, is popular because of the volatile oil it contains. *Litsea cubeba*, also known as Cubeb pepper or tailed pepper, is a type of flowering plant native to the Indonesian islands of Sumatra and Java. Its various uses include as a flavoring agent, in perfumery, and in antimicrobial products. *Litsea cubeba* essential oil, often extracted by distillation, has a fragrance reminiscent of pepper, ginger, and lemon. Apart from the uses enumerated above, *L. cubeba* oil can be used as a fungicide and bactericide. It is considered a very safe phyto-preservative and can be used as an insecticide due to its insecticidal properties (Noosidum et al., 2008).

To ensure food security and sustain human life, it is imperative to preserve food products such as cereals, grains, seeds, and nuts under optimal storage conditions, since they constitute a major proportion of staple foods worldwide. However, prolonged storage often results in infestation by insect pests such as weevils and beetles, leading to significant quantitative and qualitative losses (Lorini & Filho, 2004).

Plant-derived insecticides have gained increasing attention because they are generally biodegradable, environmentally friendly, and less persistent than synthetic pesticides. Essential oils in particular possess multiple modes of action, making them less likely to induce resistance in insect populations. Consequently, numerous studies have evaluated the insecticidal potential of essential oils from aromatic plants, including *Litsea cubeba*.

Recent studies have further strengthened interest in *Litsea cubeba* essential oil due to advances in nanoformulation technologies, encapsulation methods, and controlled-release delivery systems that improve stability, bioavailability, and biological activity. Such technological developments address major limitations associated with essential oils, particularly their volatility and rapid degradation under environmental conditions (Li et al., 2024). These advances have increased the potential of *L. cubeba* essential oil as a sustainable biopesticide for agricultural and stored-product pest management.

The objective of this review is therefore to summarize current knowledge regarding the chemical composition, insecticidal activities, mechanisms of action, and prospects of *Litsea cubeba* essential oil as a botanical insecticide.

The uses of essential oils are:

- **Aromatherapy:** It is used in aromatherapy to promote relaxation, reduce stress, and improve mood.
- **Skin and hair care:** It is used in skincare products to promote healthy skin, reduce acne, and improve hair growth.
- **Insect repellent:** It is used as a natural repellent to ward off mosquitoes and other pests.
- **Household cleaning:** It is used as a natural disinfectant and cleaning agent.
- **Perfumery:** It is used in perfumery due to its unique, citrus-like flavor.

The uses of *Litsea cubeba* include:

- **Spice:** The dried berries of the plant are used as a spice, similar to black pepper.
- **Flavor:** *Litsea cubeba* has a unique, slightly sweet, and nutty flavor.
- **Aroma:** The berries have a distinctive, aromatic scent.
- **Medicinal uses:** In traditional medicine, *Litsea cubeba* is used to treat various ailments, including digestive issues and respiratory problems.
- **Essential oil:** The plant's essential oil is used in aromatherapy and perfumery.

2. Chemical Composition of *Litsea cubeba* Essential Oil

Litsea cubeba essential oil is a translucent, yellowish liquid with a scent similar to that of *Cymbopogon citratus*. Its composition varies depending on plant part (root, stem, leaves, flowers, fruit), growing conditions, and distillation method (Bighelli et al., 2005; Tian et al., 2012). The oil comprises mainly monoterpenes, sesquiterpenes, and phenols.

Essential oil from *Litsea cubeba* contains an industrially important component, citral. Citral is used in the production of insecticides, medicines, cosmetic products, and flavoring agents (Chen et al., 2013a; Chen et al., 2016a). Other components of *L. cubeba* essential oil include limonene, citronellal, etc.; these components are responsible for the bioactivities of *L. cubeba* essential oil (Chen et al., 2013b).

Litsea cubeba essential oil contains several antioxidants, including geranial (39.4%), neral (29.5%), D-limonene (approximately 14.3%), and citral. These antioxidants contribute to the oil's overall antioxidant activity, which has been measured at 30.9%, equivalent to 167.94 µg of Trolox per mL of sample.

2.1 Major phytochemical constituents

Compound	Percentage (%)
Geranial	39.4
Neral	29.5
D-Limonene	14.3
Citral (total geranial + neral)	64.29
4,5-Epoxycarene	2.62
β-Caryophyllene	2.37
β-Pinene	2.3
Sabinene	1.9
1,8-Cineole	1.9

Compound	Percentage (%)
α-Pinene	1.7
α-Terpinolene	1.6

The biological activities of *Litsea cubeba* essential oil are largely attributed to its major constituents. Citral, comprising the isomers geranial and neral, contributes significantly to antimicrobial, antioxidant, and insecticidal activities. Other compounds such as limonene, α-pinene, β-pinene, sabinene, and γ-terpinene further contribute to repellency and toxicity against insect pests. The synergistic interactions among these compounds are believed to enhance the essential oil's broad-spectrum bioactivity.

Recent investigations have demonstrated that the chemical composition and biological properties of *L. cubeba* essential oil may vary according to geographical origin, harvest period, extraction temperature, and processing conditions. Such variations may significantly influence biological efficacy and should therefore be considered when developing standardized commercial formulations (Chung et al., 2025).

Although *Litsea cubeba* essential oil has traditionally been valued for medicinal purposes, including antimicrobial, antioxidant, and anti-inflammatory applications, its insecticidal activity has attracted growing scientific interest due to its potential role in environmentally sustainable pest management. The combination of high citral content and diverse terpenoid compounds makes the oil particularly suitable for the development of botanical insecticides.

2.2 Medicinal uses of *Litsea cubeba* essential oil

Beyond insecticidal activity, *L. cubeba* oil also exhibits medicinal properties including:

- **Digestive aid:** Helps with digestion, relieves stomach upsets, and promotes appetite
- **Pain relief:** Used to relieve pain, reduce inflammation, and alleviate arthritis symptoms
- **Antimicrobial properties:** Exhibits antibacterial, antiviral, and antifungal properties
- **Anti-inflammatory:** Helps reduce inflammation, alleviate asthma symptoms, and improve respiratory health
- **Antioxidant properties:** Helps protect against cell damage and oxidative stress

3. INSECTICIDAL ACTIVITY OF *LITSEA CUBEBA* ESSENTIAL OIL

Litsea cubeba essential oil contains secondary metabolites abundant in the plant's fruits, roots, stems, flowers, and leaves. To extract *Litsea cubeba* essential oil, a steam distillation process is employed. This essential oil comprises sesquiterpenes, monoterpenes, and phenols. There is also variation in the chemical compounds present in *Litsea cubeba* essential oil derived from the root, stem, leaves, flowers, and fruit (Bighelli et al., 2005; Tian et al., 2012). *L. cubeba* essential oil acts as an insect repellent because of its insecticidal activity. It repels various insects, including maize weevils (*Sitophilus zeamais*), Japanese termites (*Reticulitermes speratus*), and cabbage loopers (*Trichoplusia ni*).

3.1 Stored-product pests

In a study by Yang et al. (2014), the essential oil of *Litsea cubeba* fruits was found to be toxic to certain insects, including *Lasioderma serricorne* (LD_{50}: 27.33 µg/adult) and *Liposcelis bostrychophila* (LD_{50}: 71.56 µg/cm²). The fruit oil fumigant and contact toxicities were effective against beetles and booklice. Citral was more toxic than the crude oil. After 2 hours, repellency rates against *Lasioderma serricorne* and *Liposcelis bostrychophila* were 76 ± 5% and 84 ± 7% at concentrations of 78.63 and 31.58 nL/cm², respectively. Citral, d-limonene, β-pinene, and α-pinene, isolated from the fruit oil, exhibited higher repellency scores than the oil against both booklouse and cigarette beetle (Yang et al., 2014).

3.2 Mealworm beetle (*Tenebrio molitor*)

The essential oil from the leaf of *L. cubeba* was also investigated by Wang et al. (2015). The leaf oil, which was found to be rich in (E)-3,7-dimethyl-2,6-octadienal, was tested against *Tenebrio molitor* (mealworm beetle). The following findings were made: the contact toxicity of the essential oil from the leaves of L. cubeba had an LC_{50} of 21.2 µg/cm², and about 89% repellency was observed against the 10th-instar beetle after 12 hours of exposure. It was also found that the fumigation toxicities against the 10th-instar and adult beetles were recorded as LC_{50} values of 2.7 and 3.7 µl/liter, respectively (Wang et al., 2015). By implication, the results indicate that oil from the leaf of *L. cubeba* has potent insecticidal activity against *T. molitor*.

3.3 Cabbage looper (*Trichoplusia ni*)

According to Jiang et al. (2009), the commercial *L. cubeba* essential oil exhibited contact toxicity against *Trichoplusia ni* larvae, with an LD_{50} of 112.5 µg/larva. This indicates that γ-terpinene in *L. cubeba* essential oil was responsible for most of the oil's toxic effects against *T. ni* larvae.

3.4 Mites (acaricidal activity)

In studies by Pumnuan et al. (2010) and Jeon and Lee (2016), the contact and fumigation toxicities of *Litsea cubeba* fruit oil against *Luciaphorus pernicious* (mushroom mite) were LD_{50} values of 0.932 and 0.166 µg/cm³, respectively. It was also observed that toxicity increased when 0.01% *L. cubeba* essential oil was added to citronella grass or black pepper oil. The study shows that using L. cubeba fruit oil, alone or in combination with other oils, can effectively control mushroom mites.

The acaricidal activity of *L. cubeba* fruit oil against house dust mites (*Dermatophagoides pteronyssinus* and *D. farinae*) and stored-food mites (*Tyrophagus putrescentiae*) showed toxic doses (LD_{50}) of 1.83, 1.54, and 3.90 µg/cm², respectively. *L. cubeba* fruit oil could be a potent acaricidal agent against house dust and stored food mites (Jeon & Lee, 2016).

3.5 Ticks (vector pest)

More recently, *Litsea cubeba* fruit oil and its major constituent, citral (3,7-dimethyl-2,6-octadienal), were reported to exhibit significant acaricidal and repellent activities against the tick *Haemaphysalis longicornis*. The study demonstrated strong repellency and toxicity, indicating the potential application of *L. cubeba* essential oil in vector control and veterinary pest management (Park et al., 2021).

4. SUMMARY OF INSECTICIDAL ACTIVITIES

Table 1. summarizes the insecticidal and acaricidal activities of Litsea cubeba essential oil against various target species.

Target species	Plant part	Activity type	Toxicity value	Reference
Lasioderma serricorne	Fruit	Contact toxicity	LD_{50} = 27.33 µg/adult	Yang et al., 2014
Liposcelis bostrychophila	Fruit	Contact toxicity	LD_{50} = 71.56 µg/cm²	Yang et al., 2014
Tenebrio molitor (10th-instar larvae)	Leaf	Contact toxicity	LC_{50} = 21.2 µg/cm²	Wang et al., 2015
Tenebrio molitor (10th-instar larvae)	Leaf	Fumigation	LC_{50} = 2.7 µl/liter	Wang et al., 2015
Tenebrio molitor	Leaf	Fumigation	LC_{50} = 3.7 µl/liter	Wang et al., 2015
Trichoplusia ni (larvae)	Commercial (fruit)	Contact toxicity	LD_{50} = 112.5 µg/larva	Jiang et al., 2009
Luciaphorus pernicious	Fruit	Fumigation	LD_{50} = 0.166 µg/cm³	Pumnuan et al., 2010
Dermatophagoides pteronyssinus	Fruit	Acaricidal	LD_{50} = 1.83 µg/cm²	Jeon & Lee, 2016
Dermatophagoides farinae	Fruit	Acaricidal	LD_{50} = 1.54 µg/cm²	Jeon & Lee, 2016
Tyrophagus putrescentiae	Fruit	Acaricidal	LD_{50} = 3.90 µg/cm²	Jeon & Lee, 2016
Haemaphysalis longicornis	Fruit	Acaricidal/repellent	Significant activity	Park et al., 2021

5. MECHANISMS OF INSECTICIDAL ACTION

Although the precise mechanisms underlying the insecticidal activity of *Litsea cubeba* essential oil are not yet fully understood, several pathways have been proposed. The major terpenoid constituents, particularly citral and limonene, are believed to interfere with insect nervous systems by disrupting neurotransmission, respiratory processes, and enzymatic activities. These disruptions may lead to paralysis, feeding inhibition, reduced reproductive performance, and eventual mortality.

Similar neurotoxic mechanisms have been reported for several terpenoid-rich essential oils, where inhibition of acetylcholinesterase activity and disruption of octopaminergic signaling pathways contribute significantly to insect mortality (Koul et al., 2008).

In addition, the essential oil's volatility enables rapid penetration into the insect respiratory system, enhancing fumigant toxicity. The presence of multiple active compounds may also reduce the likelihood of resistance development because insects are simultaneously exposed to several bioactive molecules with different modes of action.

Recent studies have shown that nanoencapsulation technologies can further enhance the insecticidal efficacy of *L. cubeba* essential oil. Nano-encapsulated formulations have demonstrated enhanced stability, prolonged persistence, and increased toxicological effects against agricultural pests such as the brown planthopper (*Nilaparvata lugens*) (Soomro et al., 2025).

6. ADVANTAGES AND LIMITATIONS OF *LITSEA CUBEBA* ESSENTIAL OIL AS A BOTANICAL INSECTICIDE

6.1 Advantages

The growing interest in *Litsea cubeba* essential oil as a botanical insecticide stems from several advantages. First, the oil is derived from a renewable natural source and is generally considered environmentally friendly. Second, its constituents are biodegradable and exhibit lower environmental persistence than many synthetic pesticides. Third, the oil possesses multiple biological activities, including contact toxicity, fumigant toxicity, repellency, and acaricidal activity. Finally, its complex chemical composition may reduce the risk of resistance development in target pest populations.

6.2 Limitations

Despite its promising potential, several limitations hinder the widespread application of *Litsea cubeba* essential oil. The oil is highly volatile and susceptible to oxidation, resulting in reduced stability and persistence under field conditions. Furthermore, variations in chemical composition due to environmental and genetic factors can affect consistency in biological performance. Commercial application is also challenged by difficulties associated with large-scale production, formulation stability, and regulatory approval.

Recent research has therefore focused on developing nanoemulsions, microencapsulation systems, and nanofiber-based delivery platforms to enhance stability, improve controlled release, and increase biological efficacy (Li et al., 2024; Peng et al., 2024).

7. RECENT ADVANCES IN FORMULATION TECHNOLOGY

One of the most important recent developments in botanical insecticide research has been the application of nanotechnology to essential oil formulations. Nanoemulsions and nano-encapsulated delivery systems improve dispersion, increase chemical stability, enhance bioavailability, and prolong biological activity.

Studies involving *Litsea cubeba* essential oil have demonstrated that nano-formulated products exhibit superior stability and biological effectiveness compared with conventional essential oil preparations. Protein-stabilized nanoemulsions of *L. cubeba* essential oil have shown improved physicochemical stability and enhanced biological performance, suggesting promising opportunities for agricultural and food preservation applications (Peng et al., 2024). Similarly, nano-encapsulated formulations have demonstrated increased toxicity against agricultural pests while reducing rapid degradation under environmental conditions (Soomro et al., 2025).

8. FUTURE PERSPECTIVES

The growing demand for environmentally friendly pest management strategies has increased interest in plant-derived insecticides. Future research on *Litsea cubeba* essential oil should focus on field-scale evaluations, optimization of extraction methods, development of stable nanoformulations, and investigation of synergistic combinations with other botanical insecticides.

Furthermore, investigations into synergistic interactions between *L. cubeba* essential oil and other botanical pesticides may provide opportunities to enhance efficacy while reducing application rates. The integration of *L. cubeba*-based products into Integrated Pest Management (IPM) programs also deserves further attention.

Further studies are also needed to assess environmental safety, non-target toxicity, economic feasibility, and regulatory requirements for commercialization. Addressing these challenges will facilitate the large-scale adoption of *L. cubeba* essential oil as a sustainable alternative to synthetic insecticides.

9. CONCLUSION

The present review demonstrates that *Litsea cubeba* essential oil possesses significant insecticidal, fumigant, repellent, and acaricidal activities against a wide range of agricultural and stored-product pests. These biological activities are primarily attributed to the presence of citral, limonene, pinene derivatives, and other terpenoid compounds. Experimental studies have demonstrated significant activity against economically important pests including *Lasioderma serricorne*, *Liposcelis bostrychophila*, *Tenebrio molitor*, *Trichoplusia ni*, *Luciaphorus pernicious*, and *Haemaphysalis longicornis*. The available evidence suggests that *L.*

cubeba essential oil represents a promising botanical alternative to synthetic pesticides and could contribute substantially to sustainable pest management programs. Its broad-spectrum activity, biodegradability, and multiple modes of action make it an attractive candidate for future pest control applications.

Despite its promising insecticidal potential, challenges associated with chemical variability, formulation stability, and large-scale application remain. Future research should focus on the development of advanced nanoformulations, evaluation under field conditions, investigation of synergistic combinations with other botanical insecticides, and assessment of long-term environmental safety. Such efforts will facilitate the commercialization and practical application of *Litsea cubeba* essential oil as a sustainable alternative to synthetic pesticides.

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