PLANT SCIENCE TODAY
ISSN 2348-1900 (online)
Vol x(x): xx–xx
https://doi.org/10.14719/pst.3244

HORIZON
e-Publishing Group

REVIEW ARTICLE

Essential oils of Lauraceae species from Vietnam: An overview chemical profiles and biological activity

Duy Hoang Truong[1,*], **Ngoc Hung Ngo**[2] **& Nguyen Tuong An Huynh**[1]

[1]Institute of Biotechnology and Food Technology, Industrial University of Ho Chi Minh City, Ho Chi Minh City 727 000, Vietnam

[2]Faculty of Fundamental Science, Industrial University of Ho Chi Minh City, Ho Chi Minh City 727 000, Vietnam

*Email: truonghoangduy@iuh.edu.vn

OPEN ACCESS

ARTICLE HISTORY

Received: 02 January 2024
Accepted: 03 March 2024

Available online
Version 1.0 : 09 May 2024

Check for updates

Additional information

Peer review: Publisher thanks Sectional Editor and the other anonymous reviewers for their contribution to the peer review of this work.

Reprints & permissions information is available at https://horizonepublishing.com/journals/index.php/PST/open_access_policy

Publisher's Note: Horizon e-Publishing Group remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Indexing: Plant Science Today, published by Horizon e-Publishing Group, is covered by Scopus, Web of Science, BIOSIS Previews, Clarivate Analytics, NAAS, UGC Care, etc
See https://horizonepublishing.com/journals/index.php/PST/indexing_abstracting

CITE THIS ARTICLE

Truong DH, Ngo NH, Huynh NTA. Essential oils of Lauraceae species from Vietnam: An overview chemical profiles and biological activity. Plant Science Today (Early Access). https://doi.org/10.14719/pst.3244

Abstract

Lauraceae is a large family widely distributed in subtropical and tropical regions of the world. More than 250 species belonging to 18 genera of Lauraceae have been recorded in Vietnam. The essential oils (EOs) of some species belonging to genera such as *Cinnamomum, Litsea, Phoebe, Machinus, Neolitsea, Dehaasia, Caryodaphnopsis, Lindera* etc. collected from Vietnam have been reported to contain many bioactive compounds and possess biological agents. The aim of the present review is to provide comprehensive information on the chemical compositions, larvicidal and antimicrobial activities of the essential oils obtained from Lauraceae plants grown in Vietnam, with the objective of facilitating their further application in pharmaceutical and industrial contexts.

Keywords

essential oils, chemical constituents, antimicrobial, larvicidal activities, Vietnam

Introduction

Lauraceae is a large family with 55 genera and 3000 species widely found in subtropical and tropical regions, predominantly in the tropical forests of Asia and America. Members of Lauraceae have been used in industrial areas, including pharmaceutical, timber, perfumery and food industries (1). The species of this family were known for its traditional medicine to treat analgesic, malaria, female genital infections, gastrointestinal infections and rheumatism (2). The EOs extracted from species within the Lauraceae were distinguished by a various chemical constituents, including terpene alcohols, esters, organic acids, ketones, terpene hydrocarbons, aldehydes, phenols, lactones and ethers (3).

In Vietnam, more than 250 species belonging to 18 genera of Lauraceae have been recorded and found in many regions of the country (4), many of which also have been used for EOs, timber and traditional remedies (5, 6). The research on the chemical components of the EOs isolated from Lauraceae species collected from Vietnam mainly focused on some species belonging to several genera, including *Cinnamomum, Litsea, Phoebe, Machinus, Neolitsea, Dehaasia, Caryodaphnopsis* and *Lindera* etc. In addition, the biological properties of many Lauraceae plants from Vietnam have been reported (7-11). Furthermore, studies have emphasized the widespread utilization of certain *Cinnamomum* species, found in Vietnam, China and India, in traditional and local medicinal practices. Specifically, *Cinnamomum camphora* was recognized for its efficacy in treating a spectrum of ailments including common colds, arthritis, bronchitis, indigestion and diarrhea (12, 13). *Cinnamomum cassia*, particularly its leaves, was employed for alleviating headaches, chills, dysentery, colic, chest tightness, diarrhea and coughs, while its branches are utilized for diabetes, indigestion and gastric inflammation (14). *Cinnamomum subavenium* was utilized for relieving abdominal pain, chest pain, hernia, diarrhea, arthritis, nausea and vomiting, utilizing its bark, fruit and leaves (15). Additionally, *C. camphora* and *C. longipaniculatum* play a crucial role in the extraction of camphor and camphor oil, serving as indispensable sources of raw materials for spices, food products, pharmaceuticals and the chemical industry (16, 17). Moreover, *Litsea* species, which are extensively found across Asia, are known for their traditional medicinal applications in addressing a range of common health issues including influenza, diarrhea, diabetes, nausea, skeletal pain and inflammation (18). Nevertheless, to date, the overall information about chemical constituents and biological effects of the EOs isolated from Lauraceae plants in Vietnam are limited (19). The objective of this review, thus, provides comprehensive summary on the chemical compositions, larvicidal and antimicrobial activities of the EOs obtained from Lauraceae species collected from Vietnam.

Volatile compounds of Lauraceae plants

Cinnamomum species

Cinnamomum, commonly known as "Quế", is a large genus belonging to Lauraceae family with about 300 species found in tropical and subtropical regions of Oceania and Australia, Asia and Americas (20). It is known for their traditional medicine to cure indigestion, cough, cold and microbial infections. Many studies showed that stem barks and leaves possess the biological properties, including antifungal, antidiabetic, anticancer, larvicidal, antibacterial, antioxidant, antitermitic, anticholinesterase, hypouricemic xanthine oxidase inhibitory and immunemodulatory activities (21). In Vietnam, more than 45 Cinnamomum species have been recorded (4). According to some reports on chemical patterns of *Cinnamomum* species from Vietnam, the samples were mainly collected from several regions of central to north of Vietnam. Leaves were the most frequently utilized plant part for EO extraction, succeeded by stem bark, stem, root bark and wood (7-11). The EOs derived from *Cinnamomum* species predominantly comprised oxygenated monoterpenes. This was followed by a composition of monoterpene hydrocarbons, oxygenated sesquiterpenes, sesquiterpene hydrocarbons, diterpenoids and various aliphatic compounds (7-11).

A large number of *Cinnamomum* plants collected from Bach Ma National Park were reported to to exhibit a wide range of chemical compositions in their EOs. As a result, the principal constituents of the leaf EOs in *C. sericans* were identified as spathulenol, α-pinene and caryophyllene oxide. In contrast, the EO of *C. durifolium* was predominantly composed of ρ-cymene, limonene and α-phellandrene (22). The EOs of *C. magnificum* were characterized by a high concentration of bicyclogermacrene, caryophyllene oxide and β-caryophyllene. Conversely, the EOs of C. *iners* predominantly contained β-caryophyllene, caryophyllene oxide and spathulenol (22). Furthermore, the chemical compounds of the leaf EOs from *C. damhaensis* collected at various times throughout the year from Bach Ma National Park, displayed considerable variability. Specifically, the oil extracted in July was distinguished by a predominance of linalool, β-selinene, selin-11-en-4α-ol and an intermedeol isomer. In contrast, the EO gathered in August was primarily composed of linalool, α-pinene, 1,8-cineole and β-pinene (23, 24). The EOs isolated from the leaves and stem bark of *C. kunstleri* were identified as being particularly abundant in methyl eugenol, 1,8-cineole, terpinen-4-ol and α-pinene. Conversely, the EOs derived from the leaves and stem barks of *C. cambodianum* were primarily composed of linalool and terpinen-4-ol (23, 25). Similarly, aromadendrene and α-seliene were the most component in the EOs of *C. kunstleri* leaves and stem barks respectively, followed by β-caryophyllene and α-copaene (23, 25). The leaf EOs obtained from another *Cinnamomum* plants grown in Bach Ma National Park, *C. curvifolium* contained benzyl cinnamate, benzyl benzoate and hexadecanoic acid as the main compounds while eugenol and 1,8-cineole were the most constituent in the leaf EOs of *C. mairei* and *C. caryophyllus* respectively (23).

Pu Huong Nature Reserve was a location which also had various *Cinnamomum* species. Accordingly, the leaf EOs of *C. ovatum* leaves and stem barks were mainly composed of eugenol, eugenyl acetate, linalool and α-pinene (24) while 1,8-cineole, α-pinene, β-pinene and α-copaene were the major components in the oils of the same plant parts of *C. mairei* (26). Moreover, the leaf EO of *C. tetragonum* mainly contained (E)-cinnamaldehyde, cis-geraniol and cinnamyl acetate whereas the stem bark oil was characterized by the predominance of cis-geraniol, geranyl acetate and (E)-β-farnesene (27). The main components of the EOs of *C. curvifolium* leaves were β-pinene, sabinene, camphene and (E)-cinnamaldehyde while α-copaene, 1,8-cineole, α-pinene and δ-cadinene were recorded as the major components in the stem bark oil towards the same species (26). Finally, the leaf oil of *C. tonkinense* collected from Pu Huong Nature Reserve to was mainly composed of linalool, β-phellandrene and 1,8-cineole (24).

Other studies have also reported the chemical components of EOs extracted from some *Cinnamomum* species collected from other regions of Vietnam. Accordingly, the leaf EOs of *C. doederleinii* var. *raoanensis* from Pu Hoat Nature Reserve mainly possessed linalool, (E)-nerolidol, caryophyllene oxide and γ-cadinene while the leaf oil of *C. scalarinervium* was found to be rich in sabinene, α-pinene, artemisia triene and bicyclogermacrene (7). The main components of *C. longipetiolatum* EOs from Pu Hoat Nature Reserve were composed of linalool, hotrienol and *cis*-linalool oxide whereas camphor, geranial and neral were the major constituents in the EO of *C. polyadelphum* from the same location (24). The EOs of *C. glaucescens* and *C. verum* from Ben En National Park contained geraniol and bicyclogermacrene respectively as the riches component (28). In addition, the leaf and bark oils of *C. cassia* from

Ben Tre and Yen Bai provinces were characterized by the predominance of (E)-cinnamyl acetate and (E)-cinnamaldehyde (29, 30) while the bark oil of *C. illicioides* grown in Thai Nguyen Province contained a mixture of eugenol, terpinen-4-ol, δ-cadinene and α-copaene (31). The major constituents of the EO of the *C. parthenoxylon* Root bark from Lam Dong province were benzyl benzoate, cadinene and δ-cadinol while safrole, elemicin and methyl eugenol were the main constituents in the wood oils (32). The leaf oil of *C. camphora* from Ha Tay province was found to be abundant in linalool, camphor and α-terpineol. Finally, 2-methylene-3-buten-1-yl benzoate was the most abundant component in the leaf, stem and wood EOs of *Cinnamomum* sp. grown in Ha Bac province while safrole and camphor were the main components in the root EOs isolated from this plant (33).

Litsea species

Litsea, commonly known as "Bời lời" in Vietnamese, includes deciduous or evergreen trees or shrubs belonging to Lauraceae family (4). The genus contains about 200 species, which are major found in subtropical and tropical regions throughout the world (34). Some plant parts of *Litsea* species were broadly used as traditional medicine. Barks, roots, stems, velamina and leaves of *Litsea* plants were used to treat cold, stoma chache, pain, arthritis, traumatic injury and diarrhea while fruits were used to cure gastrointestinal diseases pain and asthma (34). Furthermore, *Litsea* plants have been reported to contained various bioactive constituents belonging to alkaloids, flavonoids, butenolactones, terpenoids, butanolides amides, fatty acids, lignans, steroids and megastigmane have been reported (34, 35).

The EOs extracted from *Litsea* species predominantly consist of oxygenated monoterpenes and monoterpene hydrocarbons along with sesquiterpene hydrocarbons. Subsequently, these are followed by oxygenated sesquiterpenes and non-terpene compounds in their chemical compositions (8, 36). The chemical constituents of the EOs of some *Litsea* species from Bach Ma National Park have been reported (8, 36). Accordingly, the leaf and stem EOs of *L. eugenoides* from Bach Ma National Park were found to be rich in limonene and α-phellandrene (36). Moreover, the major component in the EO of *L. helferi* leaves mainly contained limonene, β-caryophyllene, bicyclogermacrene and bicycloelemene whereas sabinene, along with α-pinene, γ-terpinene, limonene and terpinen-4-ol were the main constituents in the EO of *L. ferruginea* leaves. The EOs extracted from the *L. verticillata* leaves contained linalool, α-pinene and β -pinene as the major compounds while the leaf EO of *L. glutinosa* was found to be abundant in (E)-β-ocimene, α-pinene and β-pinene. Significantly, (Z)-citral emerged as the predominant constituent in the EOs derived from the stem, leaf, root and fruit of *L. cubeba*, followed by sabinene, limonene and linalool (8).

The chemical compositions of *L. cubeba* collected from seven regions of northern Vietnam have been reported (37, 38). Accordingly, 1,8-cineole, sabinene and α-terpineol were the major constituents in the leaf EOs of the species grown in Lang Son, Thanh Hoa and Yen Bai provinces whereas the sample from Thai Nguyen province was found to be rich in 1,8-cineole, geranial and neral (37). The leaf oil of *L. cubeba* collected from Dien Bien province were mainly composed of sabinene, linalool and α-pinene (37) while linalool was the riches component in the leaf oils of *L. cubeba* from Phu Tho province (38) and Ba Vi mountain (37).

The major volatile components of 2 *Litsea* species, including *L. umbellata* and *L. iteodaphne* from Pu Hoat Nature Reserve contained β-caryophyllene, β-pinene, germacrene D and α-pinene (39) while bicyclogermacrene, decanal and α-pinene were the major components on the leaf oil of *L. viridis* collected from the same location (40). The leaf EO of *Litsea acutivena* collected from Pu Huong Nature Reserve was mainly composed of α-phellandrene, α-pinene and β-pinene (41) while the leaf oil of another *Litsea* species, *Litsea firma* var. *austroannamensis*, grown in this region was indicated by the predominance of nerol, (E)-β-ocimene and cis-geraniol (42). Finally, the EO of *L. euosma* leaves from Pu Mat National Park contained sabinene, β-pinene and α-pinene as the major components (43).

Phoebe species

The chemical components of the leaf EOs of 2 *Phoebe* plants collected from Central of Vietnam such as *Phoebe paniculata* and *Phoebe tavoyana*. Accordingly, the oil of the first species grown in Pu Mat National Park was found to be abundant in β-caryophyllene, germacrene D and sabinene while the EO of the later plant from Vu Quang National Park included bicyclogermacrene, germacrene D and sabinene as the main compounds. Notably, the stem EO of *P. tavoyana* was made of o-cymene, ar-turmerone, spathulenol and α-pinene (11). Finally, the leaf EO of *P. angustifolia* grown in Sao La Nature Reserve was found to be rich in spathulenol, n-hexadecanoic acid and sabinene (44) while α-pinene, β-pinene and camphene were the major compounds in the EO of *P. angustifolia* leaves from Pu Hoat Nature Reserve (40).

Neolitsea species

The chemical constituents of EOs obtained from 3 species belonging to the genus *Neolitsea* collected from Vu Quang National Park and Nghe An province have been reported. Accordingly, the leaf EO of *N. buisanensis* from Vũ Quang National park contained hexadecanoic acid, (Z)-13-docosenamide and limonene as the major constituents. The stem EO was mainly consisted of phytol, (Z)-13-docosenamide and limonene while the fruit oil was found to be abundant in 1,8-cineole, (Z)-13-docosenamide and sabinene (9). Finally, the leaf EOs of 2 *Neolitsea* plants from Vu Quang National park and Nghe An province, *N. ellipsoidea* and *Neolitsea polycarpa*, mainly contained (E)-β-ocimene and linalool (40).

Machinus species

The chemical profiles of the leaf EOs extracted from some *Machinus* plants have been reported by previous studies. The oil of *M. Japonica* from Ba Vi mountain was indicated by the predominance of α-phellandrene, p-cymene and β-phellandrene (10) while (E)-nerolidol, globulol and selin-11 -en-4α-ol were the major components in the EO of

Machilus grandifolia grown in Thua Thiên Hue province (40). The main components of *M. velutina* EO from Nghe An province was found to be (E)-β-ocimene, (Z)-β-ocimene and bicycloelemene (36) whereas the oil of *M. balansae* from Pu Mat National Park was mainly composed of bicyclogermacrene, (E)-nerolidol and (E)-caryophyllene (40).

Other Lauraceae species

The leaf EO of *Cryptocarya concinna* collected from Thua Thien Hue province mainly contained caryophyllene oxide, (E)-caryophyllene and spathulenol whereas the leaf EO of this species from Pu Hoat Nature Reserve was found to be abundant in β-pinene, α-pinene and myrcene (40). The chemical compositions of the leaf EOs from *Cryptocarya impressa* from Pu Hoat Nature Reserve was indicated by the predominance of bicyclogermacrene, dodecanal and (E)-caryophyllene while germacrene D, bicyclogermacrene and δ-elemene were the major compounds in the leaf oil of *Cryptocarya infectoria* collected from the same location (40). The diversity of the chemical profiles in the leaf EOs of *Actinodaphne pilosa* collected from different locations in Pu Hoat Nature Reserve. Accordingly, the sample collected from 870 m in elevation contained β-caryophyllene, (Z)-β-ocimene and germacrene as the main compounds while the quantitatively significant constituents of the sample from 640 m in elevation were germacrene D, bicyclogermacrene and (Z)-β-ocimene (45). Moreover, the leaf EO of another *Actinodaphne* species, *A. velutina* from Central of Vietnam was found to be abundant in patchoulene, β-caryophyllene and 1-methyl-6-(1-methylethylidene)-bicyclo[3.1.0]hexane (46).

The chemical constituents of the leaf EOs of three *Beilschmiedia* plants from North Central of Vietnam have been also investigated (40). As a result, the oil of *Beilschmiedia yunnanensis* from Vu Quang National Park was dominated by 9-epi-(E)-caryophyllene, (E)-caryophyllene and α-humulene. The oil of *Beilschmiedia erythrophloia* from Pu Hoat Nature Reserve was found to be abundant in Bicyclogermacrene, (Z)-β-Ocimene, (E)-Caryophyllene while (E)-Caryophyllene, Germacrene D, α-Humulene were the prominent constituents in the oil of *Beilschmiedia robusta* from the same area (40). In addition, α-pinene, camphene, *β*-pinene and bicyclogermacrene were the major components in the EOs isolated from *Dehaasia cuneata and Caryodaphnopsis tonkinensis* grown in Pu Mat and Ben En National Park (47) whereas the leaf EO of *Lindera rufa* from Nghe An province was found to be rich in camphor, limonene and α-pinene (48).

The chemical constituents of the EOs obtained from Lauraceae plants grown in Vietnam are listed in Table 1.

Biological activities of Lauraceae plants from Vietnam

Antimicrobial activity

The antimicrobial effects of the EOs of 5 *Cinnamomum* species collected from north central Vietnam have been reported (24). Accordingly, the leaf and stem EOs of *C. ovatum* from Pu Huong Nature Reserve showed antimicrobial activities against 3 Gram-possitive, 3 Gram-negative bacteria and 1 yeast, including *E. faecalis, S. aureus, B. cereus, E. coli, P. aeruginosa, S. enterica* and *C. albicans* with MIC values of 64 and 64, 64 and 64, 128 and 64, 64 and 64, 128 and 16, 64 and 64, 64 and 32 µg/mL respectively whereas 64, 128, 128, 256, 256, 128, 256 µg/mL respectively were shown by the leaf oil of *C. longipetiolatum from* Pu Hoat Nature Reserve was also active against seven towards the same microorganisms. In addition, the leaf EO of *C. polyadelphum* grown in Pu Hoat Nature Reserve was active against 5 microorganisms such as *E. faecalis, S. aureus, B. cereus, S. enterica* and *C. albicans* with MIC values of 32, 64, 64, 128 and 256 µg/mL. Meanwhile, the leaf oil of *C. tonkinense* from Pu Huong Nature Reserve was found to be effective against three Gram-possitive, including *E. faecalis, S. aureus, B. cereus* with MIC values of 32, 128, 128 µg/mL. Finally, all studied strains were not inhibited by the EO isolated from *C. damhaensis* leaves grown in Bach Ma National Park (24). In addition, the antibacterial and antifungal activities of the leaf and bark EOs of *Cinnamomum cassia* collected from southern Vietnam (Ben Tre province) have been investigated. As a result, the bark oil of this plant was found to be effective against *S. aureus* and *Saccharomyces cerevisiae* with MIC values of 200 µg/mL whereas the leaf oil was inactive against these microorganisms (30). Meanwhile, *Listeria innocua,* a Gram-positive bacterium, was sensitive to the leaf oil of *Cinnamomum cassia* grown in northern Vietnam (Yen Bai province) with MIC values of 315 µg/mL (29).

The antimicrobial activities of leaf EOs of eleven Lauraceae species collected from north central Vietnam (40). Accordingly, the leaf oils of 2 *Cryptocarya* plants such as *C. concinna* and *C. infectoria grown* in Pu Hoat Nature Reserve were found to be effective against six microorganisms, including *E. faecalis, S. aureus, B. cereus, P. aeruginosa, S. enterica* and *C. albicans* with MIC values of 32 and 128, 128 and 64, 64 and 128, 128 and 64, 256 and 128, 64 and 64 µg/mL respectively while the leaf EO of another *Cryptocarya* species from the same location, *C. impressa,* had an inhibitory effect on *E. faecalis, S. aureus, Escherichia coli* (MICs = 64 µg/mL), *B. cereus* (MIC = 128 µg/mL) and *C. albicans* (MIC = 16 µg/mL) (40). In addition, the leaf oils of *Beilschmiedia erythrophloia* (Pu Hoat Nature Reserve) and *B. yunnanensis* (Vu Quang National Park) possessed antimicrobial effects against *E. faecalis, S. aureus, B. cereus* and *C. albicans* with MIC values of 32 and 64, 64 and 64, 64 and 64, 128 and 256 µg/mL respectively whereas the leaf oil of *Beilschmiedia robusta* from Pu Hoat Nature Reserve displayed activity against *E. faecalis, S. aureus* and *E. coli* with MIC values of 64 µg/mL (40).

The EO from the leaves of *Machilus balansae* from Pu Mat National Park showed antimicrobial activities against *Enterococcus faecalis* (MIC = 64 µg/mL), *Staphylococcus aureus, Bacillus cereus* (MICs = 128 µg/mL) while the leaf oil of *Neolitsea ellipsoidea* from Vu Quang National Park was active against *E. faecalis, S. aureus, B. cereus, E. coli* and *C. albicans* 16, 32, 16, 128, 128 µg/mL respectively (40). The 4 microorganisms such as *Enterococcus faecalis, Staphylococcus aureus, Bacillus cereus* and *Candida albicans* were inhibited by the leaf EO of *Litsea viridis* collected from Pu Hoat Nature Reserve with

Table 1. Major components identified from essential oils of Lauraceae from Vietnam

Scientific name	Origin	Part	Major compositions	Bioactivity	Ref.
Actinodaphne pilosa	Pu Hoat Nature Reserve (870m in elevation)	Leaf	β-Caryophyllene (14.9%), (Z)-β-ocimene (14.3%), germacrene D (12%), bicyclogermacrene (11%), (E)-β-ocimene (10.4%)	larvicidal	(45)
Actinodaphne pilosa	Pu Hoat Nature Reserve (640m in elevation)	Leaf	Germacrene D (16.2%), bicyclogermacrene (15.9%), (Z)-β-ocimene (10.1%), β-caryophyllene (9%), α-pinene (7.2%)	antimicrobial	(45)
Alseodaphne velutina	Central of Viet Nam	Leaf	β-patchoulene (25.74%), β-caryophyllene (12.81%), 1-methyl-6-(1-methylethylidene)-bicyclo[3.1.0]hexane (7.82%)	-	(46)
Beilschmiedia erythrophloia	Pu Hoat Nature Reserve	Leaf	Bicyclogermacrene (30.5%), (Z)-β-ocimene (26.1%), (E)-caryophyllene (18.3%), (E)-β-ocimene (3.6%), α-pinene (3.2%)	antimicrobial	(40)
Beilschmiedia robusta	Pu Hoat Nature Reserve	Leaf	(E)-Caryophyllene (22.5%), germacrene D (20.3%), α-humulene (13.4%), bicyclogermacrene (8.6%)	antimicrobial larvicidal	(40)
Beilschmiedia yunnanensis	Vu Quang National park	Leaf	9-epi-(E)-caryophyllene (21.2%), (E)-Caryophyllene (16.2%), α-humulene (9.9%), bicyclogermacrene (8.4%), α-pinene (6%)	antimicrobial	(40)
Caryodaphnopsis tonkinensis	Ben En National Park	Leaf	α-pinene (26.8%), *β*-pinene (23.0%), bicyclogermacrene (8.5%)	antimicrobial	(47)
Cinnamomum sericans	Bach Ma National park	Leaf	Spathulenol (14.5%), α-pinene (9.3%), caryophyllene oxide (9.3%), sabinene (8.0%), β-caryophyllene (7.1%)	-	(22)
Cinnamomum durifolium	Bach Ma National park	Leaf	ρ-Cymene (15.6%), limonene (13.9%), α-phellandrene (9.2%), spathulenol (7.4%), benzyl benzoate (6.5%)	-	(22)
Cinnamomum magnifium	Bach Ma National park	Leaf	Bicyclogermacrene (33.9%), β-caryophyllene (25.5%), caryophyllene oxide (7.5%), bicycloelemene (7.2%), α-copaene (6.4%)	-	(22)
Cinnamomum iners	Bach Ma National park	Leaf	β-Caryophyllene (35.9%), caryophyllene oxide (12.6%), spathulenol (5.2%)	-	(22)
Cinnamomum doederleinii var. *raoanensis*	Pù Hoạt Natural Reserve	Leaf	Linalool (41.7%), (E)-nerolidol (12.4%), caryophyllene oxide (8.5%), γ-cadinene (4.4%)	-	(7)
Cinnamomum scalarinervium	Pu Hoat Natural Reserve	Leaf	Sabinene (26.6%), α-pinene (8.8%), artemisia triene (7.1%), bicyclogermacrene (6.6%), β-pinene (6.1%)	-	(7)
Cinnamomum glaucescens	Ben En National Park	Leaf	Geraniol (36.2%), terpinen-4-ol (19.7%), α-pinene (6%), sabinene (6%), limonene (5.2%)	-	(28)
Cinnamomum verum	Ben En National Park	Leaf	Bicyclogermacrene (11.2%), β-bisabolene (7.7%), Caryophyllene oxide (5.6%), cadinene (4%), linalool oxide (3.8%)	-	(28)
Cinnamomum curvifolium	Pu Huong Natural Reserve	Leaf	β-Pinene (23.8%), sabinene (14%), camphene (12.1%), (E)-cinnamaldehyde (8.9%), cis-geraniol (7.3%)	-	(26)
Cinnamomum curvifolium	Pu Huong Natural Reserve	Stem bark	α-Copaene (14.2%), 1,8-cineole (10%), α-pinene (6.4%), δ-cadinene (5.9%), τ-cadinol (5.7%), α-santalol (5.7%)	-	(26)
Cinnamomum curvifolium	Bach Ma National Park	Leaves	Benzyl cinnamate (29.9%), benzyl benzoate (22.1%), hexadecanoic acid (7.5%), tetradecanol (5.5%), dodecanoic acid (4.6%)	-	(23)
Cinnamomum mairei	Pu Huong Natural Reserve	Leaf	1,8-Cineole (23.1%), α-pinene (13.1%), β-pinene (9%), α-copaene (7.1%), δ-3-carene (4.1%)	-	(26)
Cinnamomum mairei	Pu Huong Natural Reserve	Stem bark	α-Pinene (15.5%), 1,8-cineole (14.6%), β-pinene (10.5%), α-copaene (7.5%), (E)-cinnamaldehyde (6.5%)	-	(26)

Cinnamomum mairei	Bach Ma National Park	Leaf	Eugenol (39.7%), neryl acetate (14.9%), eugenol acetate (13.7%), 1,8-cineole (13%)	-	(23)
Cinnamomum kunstleri	Bach Ma National Park	Stem bark	1,8-Cineole (25.3%), α-terpineol (10.7%), terpinen-4-ol (6.7%), α-pinene (5.3%)	-	(25)
Cinnamomum kunstleri	Bach Ma National Park	Leaf	Methyl eugenol (22.5%), terpinen-4-ol (19.2%), 1,8-cineole (7.4%), α-pinene (4.4%), γ-terpinen (4.4%)	-	(23)
Cinnamomum rigidifolium	Bach Ma National Park	Stem bark	Aromadendrene (26%), β-caryophyllene (17.2%), α-copaene (5.7%), caryophyllene oxide (5.6%)	-	(25)
Cinnamomum rigidifolium	Bach Ma National Park	Leaf	α-Seliene (24.5%), β-caryophyllene (23%), α-copaene (7.2%), germacrene D (5%)	-	(23)
Cinnamomum cambodianum	Bach Ma National Park	Leaf	Linalool (33.1%), terpinen-4-ol (12.3%), cis-sabinene hydrate (6.2%), santolina triene (4.9%), α-terpienol (4.6%)	-	(23)
Cinnamomum cambodianum	Bach Ma National Park	Stem bark	Linalool (27%), limonene (23.4%), terpinen-4-ol (9.8%), α-phellandrene (9.5%), (E)-β-ocimene (5.9%)	-	(25)
Cinnamomum ovatum	Pu Huong Nature Reserve	Leaf	Eugenol (70.5%), eugenyl acetate (9.5%), linalool (5.9%), α-pinene (2.1%)	antimicrobial larvicidal	(24)
Cinnamomum ovatum	Pu Huong Nature Reserve	Stem	Eugenol (71.2%), eugenyl acetate (9.3%), linalool (8.3%), α-pinene (1.6%)	-	(24)
Cinnamomum tonkinense	Pu Huong Nature Reserve	Leaf	Linalool (32.2%), β-phellandrene (23.1%), 1,8-cineole (9.8%), α-phellandrene (4.8%)	antimicrobial larvicidal	(24)
Cinnamomum damhaensis	Bach Ma National Park	Leaf	Linalool (44.8%), β-selinene (19.1%), selin-11-en-4α-ol (7.3%), intermedeol isomer (5.8%)	larvicidal	(24)
Cinnamomum damhaensis	Bach Ma National Park	Leaf	Linalool (13.3%), α-pinene (12.7%), 1,8-cineole (8.5%), β-pinene (8.4%)	-	(23)
Cinnamomum longipetiolatum	Pu Hoat Nature Reserve	Leaf	Linalool (75.7%), hotrienol (3.2%), cis-linalool oxide (3.2%), α-pinene (2.9%)	antimicrobial larvicidal	(24)
Cinnamomum polyadelphum	Pu Hoat Nature Reserve	Leaf	Camphor (32.2%), geranial (16.6%), neral (11.7%), limonene (5.4%), α-pinene (4.3%)	antimicrobial larvicidal	(24)
Cinnamomum caryophyllus	Bach Ma National Park	Leaf	1,8-Cineole (22.4%), α-pinene (11%), camphene (10%), p-cymene (8.7%), camphor (7.4%)	-	(23)
Cinnamomum camphora	Ha Tay province	Leaf	Linalool (91.1%), camphor (2.3%), α-terpineol (l.8%)	-	(56)
Cinnamomum parthenoxylon	Lam Dong province	Root bark	Benzyl benzoate (52%), cadinene (5.4%), δ -cadinol (5%), calamenene (4.5%)	-	(32)
Cinnamomum parthenoxylon	Lam Dong province	Wood	Safrole (90.3%), elemicin (2.6%), methyl eugenol (1.3%)	-	(32)
Cinnamomum cassia	Ben Tre province	Bark	(E)-Cinnamaldehyde (91.5%), (E)-cinnamyl acetate (6.5%) (22)	antimicrobial	(30)
Cinnamomum cassia	Ben Tre province	Leaf	(E)-Cinnamyl acetate (62.8%), (E)-cinnamaldehyde (28.2%), 2-methylbenzofuran (7.3%)	antimicrobial	(30)
Cinnamomum cassia	Yen Bai province	Leaf	Trans-cinnamaldehyde (90.08%), trans-cinnamyl acetate (4.69%)	antimicrobial	(29)
Cinnamomum illicioides	Thai Nguyen province	bark	Eugenol (41.2%), terpinen-4-ol (10.4%), δ-cadinene (5.6%), α-copaene (4.1%)	-	(31)
Cinnamomum tetragonum	Pu Huong Nature Reserve	Leaf	(E)-Cinnamaldehyde (41.0%), cis-geraniol (33.8%), cinnamyl acetate (3.5%)	-	(27)
Cinnamomum tetragonum	Pu Huong Nature Reserve	Stem bark	cis-Geraniol (65.1%), geranyl acetate (14.8%), (E)-β-farnesene (3.7%)	-	(27)
Cinnamomum sp.	Ha Bac province	Leaf	2-Methylene-3-buten-1-yl benzoate (85.9%), spathulenol (1.3%)	-	(33)
Cinnamomum sp.	Ha Bac province	Stem	2-Methylene-3-buten-1-yl benzoate (92.4%), linalool (2.2%)	-	(33)
Cinnamomum sp.	Ha Bac province	Wood	2-methylene-3-buten-1-yl benzoate (44.2%), camphor (13%), α-terpineol (3.7%), safrole (3.5%), linalool (3.4%)	-	(33)
Cinnamomum sp.	Ha Bac province	Root	Safrole (63.8%), camphor (17.9%), 2-methylene-3-buten-1-yl benzoate (7.8%), 1,8-cineole (3.6%), α-terpineol (1.2%)	-	(33)

Cryptocarya concinna	Nam Dong district, Hue province	Leaf	Caryophyllene oxide (21.2%), (E)-caryophyllene (12.2%), spathulenol (12.3%), β-pinene (9%), α-pinene (8.2%)	larvicidal	(40)
Cryptocarya concinna	Pu Hoat Nature Reserve	Leaf	β-Pinene (31.3%), α-pinene (26.7%), myrcene (11.1%), (E)-β-ocimene (8.8%), (E)-caryophyllene (5.3%)	antimicrobial larvicidal	(40)
Cryptocarya impressa	Pu Hoat Nature Reserve	Leaf	Bicyclogermacrene (18.7%), dodecanal (10.8%), (E)-caryophyllene (10.8%), (E,E)-α-farnesene (7.9%), α-humulene (6.3%)	antimicrobial	(40)
Cryptocarya infectoria	Pu Hoat Nature Reserve	Leaf	Germacrene D (55.5%), bicyclogermacrene (11.4%), δ-elemene (5.1%), linalool (3.4%)	antimicrobial larvicidal	(40)
Dehaasia cuneata	Pu Mat National Park	Leaf	α-pinene (49.0%), camphene (19.5%), β-pinene (15.6%) limonene (7.5%)	antimicrobial	(47)
Lindera rufa	Nghe An province	Leaf	Camphor (67.5%), limonene (6.9 %), α-pinene (6.7%), camphene (4.7 %), β-myrcene (3.8 %)	-	(48)
Litsea firma var. *austroannamensis*	Pu Huong Nature Reserve	Leaf	Nerol (14.4%), (E)-β-ocimene (10.2%), cis-geraniol (10.2%), (E)-nerolidol (8.9%), β-caryophyllene (6.7%)	-	(42)
Litsea acutivena	Pu Huong Natural Reserve	Leaf	α-Phellandrene (30.4%), α-pinene (14.2%), β-pinene (7.3%)	-	(41)
Litsea cubeba	Phu Tho province	Leaf	Linalool (94.93%), D-limonene (1.52%), isocaryophyllene (1.27%)	antimicrobial	(38)
Litsea cubeba	Ba Vi mountain	Leaf	Linalool (91.1%), cis-linalool oxide (1.3%), trans-linalool oxide (1.2%)	-	(37)
Litsea cubeba	Lang Son province	Leaf	1,8-Cineole (47.6%), sabinene (12.5%), α-terpineol (11.9%), β-pinene (3.8%), α-pinene (3.7%)	-	(37)
Litsea cubeba	Thai Nguyen province	Leaf	1,8-Cineole (23.4%), geranial (9.7%), neral (7.4%), linalool (6.4%).	-	(37)
Litsea cubeba	Thanh Hoa province	Leaf	1,8-Cineole (44.8%), sabinene (12.1%), α-terpineol (10.5%), limonene (4.4%), α-pinene (4.2%)	-	(37)
Litsea cubeba	Yen Bai province	Leaf	1,8-Cineole (51.7%), sabinene (14.8%), α-terpineol (9.8%), α-pinene (4.6%), β-pinene (4.3%)	-	(37)
Litsea cubeba	Dien Bien province	Leaf	Sabinene (48.1%), linalool (10.1%), α-pinene (8.4%), β-pinene (7.8%), 1,8-cineole (7.5%)	-	(37)
Litsea cubeba	Bach Ma National Park	Leaf	(Z)-Citral (32.9%), sabinene (14.2%), linalool (9.5%), limonene (9.2%), terpinen-4-ol (4.0%)	-	(8)
Litsea cubeba	Bach Ma National Park	Stem	(Z)-Citral (53.2%), limonene (13.2%), sabinene (10.2%), terpinen-4-ol (5.3%), myrcene (3.3%)	-	(8)
Litsea cubeba	Bach Ma National Park	Fruit	(Z)-Citral (66.1%), allo-ocimene (7.9%), limonene (7.0%), citronellol (3.4%)	-	(8)
Litsea cubeba	Bach Ma National Park	Root	(Z)-Citral (60.0%), limonene (13.6%), α-pinene (3.6%), camphene (2.7%), β-pinene (2.7%)	-	(8)
Litsea eugenoides	Bach Ma National Park	Leaf	Limonene (25.1%), α-phellandrene (11.99%), Methyl eugenol (7.44%), (E)-β-ocimene (6.33%), α-pinene (5.18%)	-	(36)
Litsea eugenoides	Bach Ma National Park	Stem	Limonene (35.44%), α-phellandrene (16%), (E)-β-ocimene (10.78%), o-cymene (10.67%), β-myrcene (2.63%)	-	(36)
Litsea euosma	Pu Mat National Park	Leaf	Sabinene (24.9%), β-pinene (19.5%), α-pinene (11.8%), β-caryophyllene (10.8%)	-	(43)
Litsea umbellata	Pu Hoat Natural Reserve	Leaf	β-pinene (18.8%), β-caryophyllene (16.2%), α-pinene (10.4%), germacrene D (9.1%)	larvicidal	(39)
Litsea iteodaphne	Pu Hoat Natural Reserve	Leaf	β-caryophyllene (21.4%), germacrene D (15.5%), α-pinene (8.7%), β-pinene (6.6%).	larvicidal	(39)
Litsea viridis	Pu Hoat Nature Reserve	Leaf	Bicyclogermacrene (25.5%), decanal (14.4%), α-pinene (11.1%), β-pinene (8.3%)	antimicrobial	(40)

Litsea glutinosa	Bach Ma National Park	Leaf	(E)-β-Ocimene (57.4%), α-Pinene (7.8%), β-pinene (7.3%), Limonene (2.4%)	-	(8)
Litsea helferi	Bach Ma National Park	Leaf	Limonene (17.5%), β-caryophyllene (14.2%), bicyclogermacrene (13.1%), bicycloelemene (12.4%), α-phellandrene (8.0%)	-	(8)
Litsea ferruginea	Bach Ma National Park	Leaf	Sabinene (34.5%), α-pinene (10.1%), γ-terpinene (7.8%), limonene (6.9%), terpinene-4-ol (6.6%)	-	(8)
Litsea verticillata	Bach Ma National Park	Leaf	α-Pinene (26.1%), linalool (23.4%), β-pinene (11.7%), (E)-nerolidol (4.9%)	-	(8)
Machilus Japonica	Ba Vi mountain	Leaf	α-Phellandrene (60.2%), p-cymene (20.3%), β-phellandrene (10.5%)	-	(10)
Machinus velutina	Nghe An province	Leaf	(E)-β-Ocimene (9.5%), (Z)-β-ocimene (8.2%), bicycloelemene (7.1%), germacrene D (6.8%), allo-ocimene (6.4%)	-	(44)
Machilus balansae	Pu Mat National Park	Leaf	Bicyclogermacrene (41.5%), (E)-nerolidol (8.7%), (E)-caryophyllene (8.5%), (E)-β-ocimene (4.5%)	antimicrobial	(40)
Machilus grandifolia	Thua Thien Hue province	Leaf	(E)-Nerolidol (22.7%), globulol (10.2%), selin-11-en-4α-ol (6.7%), caryophyllene oxide (3.7%)	larvicidal	(40)
Neolitsea buisanensis	Vu Quang National park	Leaf	Hexadecanoic acid (11.8%), (Z)-13-docosenamide (8.4%), limonene (4.7%), α-terpinolene (4.7%), β-caryophyllene (4.7%)	-	(9)
Neolitsea buisanensis	Vu Quang National park	Stem	Phytol (12.9%), (Z)-13-docosenamide (12.5%), limonene (10.2%), α-terpinolene (4.9%)	-	(9)
Neolitsea buisanensis	Vu Quang National park	Fruit	1,8-Cineole (28.5%), (Z)-13-docosenamide (21%), sabinene (14.7%), α-terpineol (8.8%), hexadecanoic acid (5.6%)	-	(9)
Neolitsea ellipsoidea	Vu Quang National park	Leaf	(E)-β-ocimene (87.6%), (Z)-β-ocimene (3.7%), linalool (1.3%)	antimicrobial larvicidal	(40)
Neolitsea polycarpa	Nghe An province	Leaf	(E)-β-ocimene (85.6%), limonene (6.5%), allo-ocimene (1.8%)	-	(44)
Phoebe angustifolia	Pu Hoat Nature Reserve	Leaf	α-pinene (26.9%), β-pinene (20.8%), camphene (6.1%), spathulenol (5.4%), (E)-caryophyllene (5.3%)	larvicidal	(40)
Phoebe angustifolia	Sao La Nature Reserve	Leaf	Spathulenol (17%), n-hexadecanoic acid (13%), sabinene (6.4%), bicyclogermacrene (5.9%), artemisia triene (5.1%)	-	(44)
Phoebe paniculata	Pu Mat National Park	Leaf	β-Caryophyllene (12.1%), germacrene D (9.2%), sabinene (8.8%), β-cubebene (7.5%)	-	(11)
Phoebe tavoyana	Vu Quang National park	Leaf	Bicyclogermacrene (15.5%), germacrene D (13.9%), sabinene (7.0%), β-caryophyllene (7.0%)	-	(11)
Phoebe tavoyana	Vu Quang National park	Stem	o-Cymene (6.9%), ar-turmerone (6.8%), spathulenol (5.6%), α-pinene (4.1%), δ-elemene (3.4%)	-	(11)

"-": No reported data for the species mentioned in Vietnam

MIC values of 16, 64, 16 and 128 µg/mL respectively (40). Meanwhile, the leaf EO of another *Litsea* plant, *L. cubeba* grown in Phu Tho province had an inhibitory effect on 6 pathogenic bacteria, including *Aeromonas hydrophila, E. coli* (MICs = 0.96 mg/mL), *Salmonella typhimurium* (MICs = 2.89 mg/mL), *Vibrio parahaemolyticus* (MICs = 1.93 mg/mL), *V. furnissii, Edwardsiella tarda* (MICs = 0.72 mg/mL) and *Lactococcus garvieae* (MICs = 2.41 mg/mL) (38).

The leaf EOs of *Actinodaphne pilosa* collected from different locations in Pu Hoat Nature Reserve (870 and 640 m in elevation) possessed antimicrobial activities against *E. faecalis, S. aureus, B. cereus, E. coli, P. aeruginosa and C. albicans* with MIC values ranging from 16 to 128 µg/mL (45). Furthermore, the leaf EOs of 2 Lauraceae species such as *Dehaasia cuneata* and *Caryodaphnopsis tonkinensis* collected from Pu Mat and Ben En National Park have been reported to possess the antimicrobial activities against *E. faecalis, S. aureus, B. cereus, P. aeruginosa* and *C. albicans* with MIC values of 16.72 and 15.99, 21.56 and 56.78, 23.45 and 56.54, 5.37 and 57.78, 65.5 and 33.68 µg/mL respectively (47).

The chemical components of the EOs isolated from the members of Lauraceae family in Vietnam could be the major factor contributing their antimicrobial properties. For instance, trans-cinnamaldehyde was active against *Listeria innocua*, *Bacillus subtilis, Klebsiella oxytoca, Listeria monocytogenes, Pseudomonas putida*, *E. coli and S. aureus* (29). Linalool had an inhibitory effect on a large number of bacterial strains, including *S. aureus*, *P. aeruginosa*, *E. coli, Streptococcus mutans*, *S. sobrinus*, *Porphyromonas gingivalis*, *Prevotella intermedia*, *P. nigrescens*, *Fusobacteriumnucleatum* subsp. *fusiforme, F. nucleatum* subsp. *polymorphum*, *F.nucleatum* subsp. *vince ntii*, *F. nucleatum* subsp. *nucleatum*, *F. nucleatum* subsp. *animalis*, *Pasteurella multocida*, *Aggregatibacter actinomycetemcomitans*, *Listeria monocytogenes* (49-51), *A. hydrophila, S. typhimurium*, *V. parahaemolyticus*, *V. furnissii, E. tarda* and *L. garvieae* (38).

Furthermore, α-pinene had an inhibitory effect on some pathogenic bacteria, including *E. coli*, *Sclerotinia sclerotiorum*, *S. faecalis*, *S. aureus*, *S. pneumonia*, *S. pyogenes, P. aeruginosa*, *Cylindrocarpon mali*, *Mycobacterium smegmatis*, *Aspergillus niger* and *Stereum purpureum, S. epidermidis* and several fungal strains, including *C. albicans*, *Cryptococcus neoformans* and *Rhizopus oryzae* (52). Meanwhile, β-pinene possessed the antimicrobial effects against *S. aureus*, *S. epidermidis*, *Streptococcus pyogenes* and *S. pneumonia*, *C. neoformans, C. albicans* and *R. oryzae* (53). 1,8-cineole has been reported to display activity against some bacterial and fungal strains such as *P. aeruginosa, S. aureus*, *E. coli* and *C. albicans* (54). Furthermore, some bacterial and fungal strains, including *E. coli*, *S. aureus*, *B. subtilis, B. cereus*, *K. pneumonia*, *P. aeruginosa, S. cerevisiae*, *A. niger*, *Penicillium citrinum*, *Rhizopus oryzae* and *Trichoderma reesei* were inhibited by β-caryophyllene (55). Terpinen-4-ol was found to be effective against 10 strains of *Staphylococcus aureus* such as ATCC-13150, ATCC-25923, LM-40, LM-02, LM-314, LM-45, LM-116, LM-232, LM-222 and LM-297 (55). Camphor and *p*-cymene had an inhibitory effect on *E. coli*, *Cylindrocarpon mali*, *Mycobacterium smegmatis*, *S. faecalis*, *S. aureus*, *P. aeruginosa*, *C. albicans*, *Sclerotinia sclerotiorum*, *A. niger*, *Stereum purpureum* and *Sotlyfis cinerea* (52).

Larvicidal activity

The EOs of 5 *Cinnamomum* species from north central Vietnam have been reported to screen for larvicidal effects against three mosquitos, including *Aedes albopictus, Culex quinquefasciatus and A. aegypti* (24). Accordingly, after 24 h of its application, the stem oil of *C. ovatum from Pu Huong Nature Reserve* was found to be effective against *A. aegypti, A. albopictus and C. quinquefasciatus with* LC_{50} *values of* 52.51, 61.45 and 28.79µg/mL respectively while LC_{50} values of 46.74, 50.18 and 20.54 respectively were shown by the larvicidal effects of the leaf EO towards the same mosquitos after 48 h (24). The leaf EO of *C. tonkinensis* from Pu Huong Nature Reserve had an inhibitory effect on *A. aegypti, A. albopictus* and *C. quinquefasciatus* with LC_{50} values of 17.44, 42.89 and 14.05 µg/mL respectively after 24 hours of its application while the LC_{50} values of *C. tonkinensis* oil after 48h were 15.83, 42.47 and 8.72 µg/mL (24). In addition, the leaf oils of *C. damhaensis* from Bach Ma National Park *and C. polyadelphum* from Pu Hoat Nature Reserve possessed larvicidal effects against these mosquitos with LC_{50} values of 21.43 and 23.41, 43.91 and 20.66, 46.74 and 18.33 µg/mL respectively after 48h whereas 17.36 and 17.3, 39.85 and 20.79, 18.63 and 11.03 respectively were shown by the larvicidal effects of the EOs of these plants towards the same mosquitos after 48 h (24). After 24 or 48 h, the leaf oils of *C. ovatum displayed* activity against *A. aegypti* and *C. quinquefasciatus* with LC_{50} values *of* 14.12 or 13.76, 34.19 or 30.48 µg/mL respectively whereas LC_{50} values of 62.2 or 39.5, 126.8 or 76.88 µg/mL respectively shown by the larvicidal activities of the EO of *C. longepetiolatum* leaf towards the same mosquitos after 24 or 48 h (24).

After 24 h of its application, the leaf EO of *Beilschmiedia robusta, Cryptocarya concinna, C. infectoria, Phoebe angustifolia* from Pu Hoat Nature Reserve, *C. concinna, Machilus grandifolia* from Thua Thien Hue province and *Neolitsea ellipsoidea* from Vu Quang National park was found to be effective against *Aedes aegypti* with LC_{50} values *of* 24.29, 23.01, 21.43, 24.29, 32.54, 20.23 and 6.57 µg/mL respectively whereas LC_{50} values of 22.0, 16.22, 18.94, 22.46, 32.03, 16.17, 4.03 µg/mL respectively were shown by the larvicidal activities of these oil samples towards the same mosquito after 48 h (40). Moreover, after 24 h, *Aedes albopictus* were inhibited by the leaf oils of *C. concinna, C. infectoria, M. grandifolia* and *P. angustifolia* with LC_{50} values of 34.21, 61.34, 16.48 and 40.18 µg/mL respectively while these oil samples possessed larvicidal activities against *A. albopictus* LC_{50} values of 30.19, 58.8, 15.45 and 35.28 µg/mL respectively after 48 h (40). Furthermore, after 24 h of its application, the leaf EOs of *C. concinna, C. infectoria, M. grandifolia*, *N. ellipsoidea* and *P. angustifolia* had an inhibitory effect on *Culex quinquefasciatus* with LC_{50} values of 50.28, 10.82, 13.59, 7.46 and 20.7 µg/mL respectively while those displayed activity against this mosquito after 48 h with LC_{50} values of 41.89, 0.4, 11.56, 4.45 and 12.21 µg/mL respectively (40).

In addition, the leaf EOs of *Actinodaphne pilosa* collected from different locations in Pu Hoat Nature Reserve (870 and 640 m in elevation) had larvicidal effects against 3 mosquitos such as *A. aegypti, A. albopictus* and *C. quinquefasciatus* (45). Accordingly, *A. aegypti* was inhibited by the EO obtained from 2 samples (870 and 640 m in elevation) of this plant with LC_{50} values of 19.02 and 14.78 µg/mL (45). Only sample oil collected from 870 in elevation possessed the larvicidal activities against *A. albopictus* and *C. quinquefasciatus* with LC_{50} values of 24.74 and 48.06 µg/mL respectively (45). The leaf EO of 2 *Litsea* species, *L. umbellata* and *L. iteodaphne,* collected from Pu Hoat Natural Reserve displayed larvicidal effects against *Culex quinquefasciatus* and *Aedes albopictus.* As a result, the oil of *L. umbellata* was found to be effective against *A. albopictus* with 40.09 and 27.33 µg/mL respectively at 24 and 48 h of application while 36.19 µg/mL was the LC_{50} value of this sample towards the same mosquito at both 24 and 48 h (39). Meanwhile, *C. quinquefasciatus* was sensitive to the *L. iteodaphne* EO with LC_{50} values of 37.2 and 20.21 µg/mL respectively at 24 and 48 h while this oil was found to be effective against *A. albopictus* after 24 and 48 h of application with LC_{50} values of 40.04 and 16.63 µg/mL respectively (39).

Conclusion

The present review provides an overview of the chemical constituents, larvicidal and antimicrobial properties of EOs derived from Lauraceae plants in Vietnam. The EOs and their bioactive compounds isolated from various members of the Lauraceae family in Vietnam indicate the presence of promising biological agents to be applied in the near future. Antimicrobial activity and larvicidal actions of the EOs and their bioactive components from Lauraceae needs to be extensively explored to find its further application in pharmaceutical industry.

Acknowledgements

This research is supported by Institute of Biotechnology and Food Technology, Industrial University of Ho Chi Minh City, Vietnam.

Authors' contributions

DHT and NTAH designed this study, drafted the manuscript. DHT, NHN and NTAH resolved all the queries of reviewers.

Compliance with ethical standards

Conflict of interest : Authors do not have any conflict of interests to declare.

Ethical issues: None.

References

1. Damasceno CSB, Fabri Higaki NT, Dias JDFG, Miguel MD, Miguel OG. Chemical composition and biological activities of essential oils in the family Lauraceae: A systematic review of the literature. Planta Medica. Georg Thieme Verlag. 2019; Vol. 85: p. 1054-72.
2. Salleh WMNHW, Ahmad F, Yen KH, Zulkifli RM. A review on chemical constituents and biological activities of the genus *Beilschmiedia* (Lauraceae). Trop J Pharm Res. 2015;14(11):2139.
3. Dorman HJD, Deans SG. Antimicrobial agents from plants: Antibacterial activity of plant volatile oils. J Appl Microbiol. 2000 Feb;88(2):308-16. https://doi.org/10.1046/j.1365-2672.2000.00969.x
4. Hoang Ho P. Cây cỏ Việt Nam: An illustrated flora of Vietnam. Ho Chi Minh City: Youth Publishing House, Ho Chi Minh City; 2000.
5. Cheng S-S, Liu J-Y, Hsui Y-R, Chang S-T. Chemical polymorphism and antifungal activity of essential oils from leaves of different provenances of indigenous Cinnamon (*Cinnamomum osmophloeum*). Bioresour Technol. 2006 Jan;97(2):306-12. https://doi.org/10.1016/j.biortech.2005.02.030
6. Das M, Mandal S, Mallick B, Hazra J. Ethnobotany, phytochemical and pharmacological aspects of *Cinnamomum Zeylanicum* Blume. Int Res J Pharm. 2016 Nov;4(4):58-63. https://doi.org/10.7897/2230-8407.04409
7. Dai DN, Huong LT, Chau DTM, Nhan NT, Tung LT, Thao NT *et al*. Essential oils of *Cinnamomum doederleinii* var. *Raoanensis* and *C. scalarinervium* from Vietnam. Chem Nat Compd. 2020;56 (2):351-53. https://doi.org/10.1007/s00129-020-04559-6
8. Son LC, Dai DN, Thang TD, Huyen DD, Ogunwande IA. Analysis of the essential oils from five Vietnamese *Litsea* species (Lauraceae). J Essent Oil-Bearing Plants. 2014 Sep;17(5):960-71.
9. Linh LD, Ban PH, Hoi TM, Huong LT, Ogunwande IA. Compositions of essential oils from the leaf, stem and fruit of *Neolitsea buisanensis* (Lauraceae) from Vietnam. J Essent Oil-Bearing Plants. 2018 Sep;21(5):1257-65. https://doi.org/10.1080/0972060X.2018.1527729
10. Huy DQ, Van Khien P, Quang Huy D, Thi D, Huong V. Chemical composition of essential oil of *Machilus japonica* Siebold & Zucc. (Lauraceae) from Vietnam coastal pollution in the Vietnam view project chemical composition of essential oil of *Machilus japonica* Siebold & Zucc. (Lauraceae) from Vietnam. Natural Sciences and Technology. 2009; Vol. 25:81-83.
11. Linh LD, Ban PH, Dai DN, Hung NV, Thin DB, Dung VT *et al*. Analysis of essential oils from the leaf of *Phoebe paniculata* (Wall. ex Nees) nees, leaf and stem of *Phoebe tavoyana* (Meissn.) Hook. f. from Vietnam. J Essent Oil-Bearing Plants. 2019 Jan;22 (1):231-38.
12. Lee HJ, Hyun E-A, Yoon WJ, Kim BH, Rhee MH, Kang HK *et al*. *In vitro* anti-inflammatory and anti-oxidative effects of *Cinnamomum camphora* extracts. J Ethnopharmacol. 2006 Jan;103(2):208-16. https://doi.org/10.1017/S1047951106000278
13. Singh R, Jawaid T. *Cinnamomum camphora* (Kapur): Review Pharmacogn J [Internet]. 2012;4(28):1-5.
14. Ngoc TM, Lee I, Ha DT, Kim H, Min B, Bae K. Tyrosinase-inhibitory constituents from the twigs of *Cinnamomum cassia*. J Nat Prod. 2009 Jun;72(6):1205-08. https://doi.org/10.1021/np900031q
15. Hao X, Sun W, Ke C, Wang F, Xue Y, Luo Z *et al*. Anti-inflammatory activities of leaf oil from *Cinnamomum subavenium in vitro* and *in vivo*. Biomed Res Int. 2019;2019:1823149.
16. Wang J, Su B, Jiang H, Cui N, Yu Z, Yang Y *et al*. Traditional uses, phytochemistry and pharmacological activities of the genus *Cinnamomum* (Lauraceae): A review. Fitoterapia. 2020;146:104675.
17. Abeysekera WPKM, Arachchige SPG, Abeysekera WKSM, Ratnasooriya WD, Medawatta HMUI. Antioxidant and glycemic regulatory properties potential of different maturity stages of leaf of *Ceylon Cinnamon* (*Cinnamomum zeylanicum* Blume) *in*

vitro. Ohta Y, editor. Evidence-Based Complement Altern Med [Internet]. 2019;2019:2693795.

18. Wang Y-S, Wen Z-Q, Li B-T, Zhang H-B, Yang J-H. Ethnobotany, phytochemistry and pharmacology of the genus *Litsea*: An update. J Ethnopharmacol. 2016;181:66-107. https://doi.org/10.1016/j.jep.2016.01.032
19. Van Hop N, Manh Hung B, Trong HQ. Diversity of Lauraceae family in Hon Ba Nature Reserve, Khanh Hoa Province. J For Sci Technol. 2020;(9).
20. Ravindran P, Babu K, Shylaja M. *Cinnamon* and *Cassia*: The genus *Cinnamomum*. CRC Press, Boca Raton, FL; 2003.
21. Balijepalli MK, Buru AS, Sakirolla R, Pichika MR. *Cinnamomum* genus: A review on its biological activities. International Journal of Pharmacy and Pharmaceutical Sciences. Innovare Academics Sciences Pvt. Ltd. 2017;vol. 9: p. 1-11.
22. Son LC, Dai DN, Thai TH, Huyen DD, Thang TD, Ogunwande IA. The leaf essential oils of four Vietnamese species of *Cinnamomum* (Lauraceae). In: Journal of Essential Oil Research. 2013; p. 267-71. https://doi.org/10.7723/antiochreview.71.2.0267
23. Son LC, Dai DN, Thang TD, Huyen DD, Ogunwande IA. Study on *Cinnamomum* oils: Compositional pattern of seven species grown in Vietnam. J Oleo Sci. 2014 Sep;63(10):1035-43.
24. Dai DN, Chung NT, Huong LT, Hung NH, Chau DTM, Yen NT *et al*. Chemical compositions, mosquito larvicidal and antimicrobial activities of essential oils from five species of *Cinnamomum* growing wild in North Central Vietnam. Molecules. 2020 Mar;25 (6).
25. Son L, Dai D, Thang T, Huyen D, Olayiwola T, Ogunmoye A *et al*. Chemical composition of essential oils from the stem barks of three *Cinnamomum* species. Br J Appl Sci Technol. 2015 Jan;11 (5):1-7.
26. Lam NT, Chuong NT, Ngan TQ, Truong NC, Lev H. Essential oils of *Cinnamomum curvifolium* (Lour.) Nees and *Cinnamomum mairei*. J Essent Oils Nat Prod. 2019;7(2):11-14.
27. Dai DN, Lam NTT, Cuong NT, Ngan TQ, Truong NC, Ogunwande IA. Composition of essential oil of *Cinnamomum tetragonum*. Chem Nat Compd. 2020 May;56(3):545-47. https://doi.org/10.1007/s10600-020-03086-z
28. Chinh HV, Luong NX, Thin DB, Dai DN, Hoi TM, Ogunwande IA. Essential oils leaf of *Cinnamomum glaucescens* and *Cinnamomum verum* from Vietnam. Am J Plant Sci. 2017;08 (11):2712-21.
29. Trinh N-T-T, Dumas E, Le Thanh M, Degraeve P, Ben C, Gharsallaoui A *et al.* Effect of a Vietnamese *Cinnamomum cassia* essential oil and of its major component trans-cinnamaldehyde on the cell viability, membrane integrity, membrane fluidity and 2 proton motive force of *Listeria innocua*. Dynamique Microbienne aux Interfaces Aliment.
30. Le VD, Tran VT, Dang VS, Nguyen DT, Dang CH, Nguyen TD. Physicochemical characterizations, antimicrobial activity and non-isothermal decomposition kinetics of *Cinnamomum cassia* essential oils. J Essent Oil Res. 2020 Mar;32(2):158-68. https://doi.org/10.1080/10412905.2019.1700834
31. Giang PM, König WA, Son PT. Chemical constituents of the essential oil from the bark of *Cinnamomum illicioides* A. Chev. from Vietnam. J Nat Med. 2006 Jul;60(3):248-50. https://doi.org/10.1007/s11418-006-0039-1
32. Dũng NX, Mõi LD, Hung ND, Leclercq PA. Constituents of the essential oils of *Cinnamomum parthenoxylon* (Jack) Nees from Vietnam. J Essent Oil Res. 1995;7(1):53-56. https://doi.org/10.1080/10412905.1995.9698462
33. Dũng NX, Van Khiên P, Vinh NTQ, Lê HT, Van De Ven LJM, Leclercq PA. 2-Methylene-3-buten-1-yl Benzoate: The major constituent of the leaf, stem and wood oils from "Re Gúng," a *Vietnamese Cinnamomum* sp. tree. J Essent Oil Res. 1997;9(1):57-61. https://doi.org/10.1080/10412905.1997.9700715
34. Kong DG, Zhao Y, Li GH, Chen BJ, Wang XN, Zhou HL *et al*. The genus *Litsea* in traditional Chinese medicine: An ethnomedical, phytochemical and pharmacological review. Journal of Ethnopharmacology. Elsevier Ireland Ltd. 2015; Vol. 164: p. 256-64. https://doi.org/10.1016/S0378-8741(15)00185-3
35. Wang H, Liu Y. Chemical composition and antibacterial activity of essential oils from different parts of *Litsea cubeba*. Chem Biodivers. 2010 Jan;7(1):229-35. https://doi.org/10.1002/cbdv.200800349
36. Le C, Tran D, Do N, Duong D, Tran H. Chemical composition of essential oil of the *Litsea eugenoides* A. Chev. from Bach Ma National park. 5th Natl Sci Conf Ecol Biol Resour. 2013;1205-09.
37. Bighelli A, Muselli A, Casanova J, Tam NT, Anh V Van, Bessière JM. Chemical variability of *Litsea Cubeba* leaf oil from Vietnam. J Essent Oil Res. 2005;17(1):86-88. https://doi.org/10.1080/10412905.2005.9698839
38. Nguyen HV, Caruso D, Lebrun M, Nguyen NT, Trinh TT, Meile JC *et al*. Antibacterial activity of *Litsea cubeba* (Lauraceae, May Chang) and its effects on the biological response of common carp *Cyprinus carpio* challenged with *Aeromonas hydrophila*. J Appl Microbiol. 2016 Aug;121(2):341-51.
39. Dai DN, Hung ND, Chung NT, Huong LT, Hung NH, Ogunwande IA. Chemical constituents of the essential oils from the leaves of *Litsea umbellata* and *Litsea iteodaphne* and their mosquito larvicidal activity. J Essent Oil-Bearing Plants. 2020;23(6):1334-44. https://doi.org/10.1080/0972060X.2020.1858347
40. Chau DTM, Chung NT, Huong LT, Hung NH, Ogunwande IA, Dai DN *et al*. Chemical compositions, mosquito larvicidal and antimicrobial activities of leaf essential oils of eleven species of *Lauraceae* from Vietnam. Plants. 2020 May;9(5).
41. Dai DN, Lam NTT, Dung NA, Huong LT, Chau DTM, Ogunwande IA. Composition of essential oils from *Litsea acutivena* Hayata. Am J Plant Sci. 2019;10(04):615-21. https://doi.org/10.4236/ajps.2019.104044
42. Dai DN, Lam NTT, Dung NA, Huong LT, Chau DTM, Ogunwande IA. Composition of essential oils from *Litsea firma* var. *austroannamensis* from Vietnam. Chem Nat Compd. 2020 May;56(3):542-44.
43. Thang TD, Hien HH, Thuy TX, Dung NX. Volatile constituents of the leaf oil of *Litsea euosma* J. J. Sm. from Vietnam. J Essent Oil-Bearing Plants. 2006;9(2):122-25. https://doi.org/10.1080/0972060X.2006.10643482
44. Thang TD, Dai DN, Thai TH, Ogunwande IA, Hoang Q, Viet C *et al*. Essential oils of *Phoebe angustifolia* Meisn., *Machilus velutina* Champ. ex Benth. and *Neolitsea polycarpa* Liou (Lauraceae) from Vietnam. Nat Prod. 2013;7:192-200.
45. Chung NT, Huong LT, Hung NH, Hoi TM, Dai DN, Setzer WN. Chemical composition of *Actinodaphne pilosa* essential oil from Vietnam, mosquito larvicidal activity and antimicrobial activity. Nat Prod Commun. 2020;15(4).
46. Cuong NT, Ban PH, Chung M Van. Chemical composition and antioxidant activity of the essential oil of *Alseodaphne velutina* Chev. from Viet Nam. Nat Prod Res. 2022 Jan;36(2):617-20.
47. Ogunwande IA, Huong LT, Chau DTM, Dai DN. Essential oils of Lauraceae: Constituents and antimicrobial activity of *Dehaasia cuneata* (Blume) Blume and *Caryodaphnopsis tonkinensis* (Lecomte) airy-shaw from Vietnam. Rec Nat Prod. 2021 Dec;(2):1-6.
48. Dai DN, Thang TD, Pino JA. Essential oil of *Lindera rufa* Hook. f. leaves from Vietnam. J Essent Oil-Bearing Plants. 2013;16(6):832-34. https://doi.org/10.1080/0972060X.2013.813269

49. Park SN, Lim YK, Freire MO, Cho E, Jin D, Kook JK. Antimicrobial effect of linalool and α-terpineol against Periodontopathic and Cariogenic bacteria. Anaerobe. 2012 Jun;18(3):369-72.

50. Gao Z, Van Nostrand JD, Zhou J, Zhong W, Chen K, Guo J. Anti-listeria activities of *Linalool* and its mechanism revealed by comparative transcriptome analysis. Front Microbiol. 2019;10.

51. Herman A, Tambor K, Herman A. Linalool affects the antimicrobial efficacy of essential oils. Curr Microbiol. 2016 Feb;72(2):165-72. https://doi.org/10.1007/s00284-015-0933-4

52. Prudent D, Perineau F, Bessiere JM, Michel G, Bravo R. Chemical analysis, bacteriostatic and fungistatic properties of the essential oil of the *Atoumau* from *Martiniqu*e (*Alpinia speciosa* K. schum.). J Essent Oil Res. 1993;5(3):255-64. https://doi.org/10.1080/10412905.1993.9698218

53. Rivas da Silva AC, Lopes PM, Barros de Azevedo MM, Costa DCM, Alviano CS, Alviano DS. Biological activities of α-pinene and β-pinene enantiomers. Molecules. 2012 May;17(6):6305-16.

54. Hendry ER, Worthington T, Conway BR, Lambert PA. Antimicrobial efficacy of *Eucalyptus* oil and 1,8-cineole alone and in combination with chlorhexidine digluconate against microorganisms grown in planktonic and biofilm cultures. J Antimicrob Chemother. 2009 Oct;64(6):1219-25.

55. Zahi MR, Liang H, Yuan Q. Improving the antimicrobial activity of D-limonene using a novel organogel-based nanoemulsion. Food Control. 2015 Apr;50:554-59. https://doi.org/10.1016/j.foodcont.2014.10.001

56. Duñg NX, Van Khiên P, Chiên HT, Leclercq PA. The essential oil of *Cinnamomum camphora* (L.) Sieb. var. *Linaloolifera* from Vietnam. J Essent Oil Res [Internet]. 1993 Jul 1;5(4):451-53.