A systematic review of the essential oils and biological activities of the genus *Lindera* (Lauraceae)

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The genus *Lindera* consists of approximately 100 species that are widely distributed in tropical and subtropical areas throughout the world. It is represented by widely well-known medicinal and aromatic plants that produce essential oil. This review attempts to summarise the information on the essential oils of *Lindera* species together with their chemical composition and biological properties. The data and information were collected via an electronic search engine, namely: Scopus, ScienceDirect, Google Scholar, PubMed, and SciFinder. A total of thirteen *Lindera* species have been reported for their essential oils and biological activities. Sesquiterpenes were identified as the major group components in *Lindera* species with the presence mainly of β-caryophyllene, as well as monoterpenes which were dominated by limonene, α-copaene, α-pinene, and 1,8-cineole. In addition, the *Lindera* essential oils also displayed various biological activities including anti-allergic, anti-arthritic, antivirus, antibacterial, anticancer, anti-inflammatory, antitumor, and cytotoxicity. The outcome of these studies will further support the therapeutic potential of the genus *Lindera* and provide convincing evidence for its future clinical applications in modern medicine.

Keywords: Essential oil; *Lindera*; β-caryophyllene; limonene; anti-inflammatory; antibacterial

1. INTRODUCTION

Lauraceae, one of the most primitive families of plants, belongs to the Magnoliidae subclass, a family of pantropical plants that includes trees and shrubs. It is composed of approximately 55 subgenera totalling over 3,000 species. The family is highly diversified in Southeast Asia, Madagascar, Northern South America, and the east coast of Brazil [1-3]. The genus *Cinnamomum, Litsea, Lindera*, *Neolindera*, and *Parabenzoin* are the example of well-known subgenera in Lauraceae family. In China, there are about 25 genera and 445 species that distribute over the low and moderate altitude ranges from the southwest to the south. The genera *Sinosassafras* and *Sinopora* are two of them that are native to China, while *Laurus* and *Persea* are the commercially grown genera [4]. Besides, in Malaysia, there are about 213 species from 16 genera and locally known as '*medang'* [5].

Lindera is a genus of about 100 species of flowering plants in the family Lauraceae. It can be found all over the world in tropical, subtropical climates, and temperate zones of Asia and Midwestern America [6]. The most common *Lindera* species are *L. aggregata*, *L. chunii merr*, *L. communis*, *L. erythrocarpa*, *L. fragrans*, *L. glauca*, *L. glucida*, *L. megaphylla*, *L. melissifolia*, *L. nacusua*, *L. neesiana*, *L. obtusiloba*, *L. pipericarpa*, *L. pulcherrima*, *L. radix*, *L. strychnifolia*, and *L. umbellate*. The specific floral morphology of the Lauraceae family can be used to identify it. The bark has many lenticels and is smooth and leathery. After being cut, the inner bark emits sap that ranges in colour from pale yellow to pale brown that is fragrant, yellow, orange, reddish, and pinkish. The leaves are plain, stipule-free, opposite, spiral, whorled, and alternate. The flower is differently accrescent and are bisexual, actinomorphic, tiny, regular, greenish-white, or yellow in colour, aromatic, and trimerous [7]. Most of the flowers have six sepals that are arranged in two cycles. The fruits, which are baccate or drupaceous and frequently seated or surrounded by a persistent and cup-shaped corolla, have taxonomic significance. Many tropical species in the Lauraceae family have persistent leaves, which stay on the plant even when they are no longer useful [8].

Essential oils have been utilised for thousands of years for their therapeutic and medical effects. Ancient civilizations like Egypt, Greece, and Rome are known using essential oils in their religious rituals. Essential oils as secondary metabolites involve complex mixtures of natural compounds with versatile organic structures representing useful medicinal properties. Essential oils are important natural sources and are used as raw materials to produce fragrance compounds in cosmetics, as flavouring additives for food and beverages, as scenting agents in a variety of household products, and as intermediates in the synthesis of other perfume chemicals. Meanwhile, essential oils from aromatic and medicinal plants have been known since antiquity to possess biological activities, most notably antibacterial, antifungal, and antioxidant properties [9-15].

The essential oils from *Lindera* species have been broadly studied and investigated, the most reported species are *L. aggregata, L. obtusiloba,* and *L. glauca*. Thus, the current reviews of the essential oils were aimed to simplify and compile the information available. The information was obtained via electronic searches in Scopus, PubMed, ScienceDirect, and Google Scholar. Furthermore, this review will provide an overview of the chemical compositions, biological activities, and some of the medicinal uses of previously published reports on essential oils of *Lindera* species.

2. SEARCH STRATEGY

Searches on Scopus, PubMed, ScienceDirect, and Google Scholar were used to carry out the systematic review. "*Lindera*," "essential oil," and "biological activity" were the search terms used. All articles from the start of the database up through June 2023 have been viewed. The protocol for performing the current study was developed according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement (PRISMA) [16]. The flowchart for article identification and selection is shown in Figure 1.

Titles and abstracts were reviewed after duplicate articles were removed, and the inclusion and exclusion criteria were used. After thoroughly reading each article that resulted from the earlier stages, the inclusion and exclusion criteria were once more applied. The articles that met all criteria at the end of the last stage were chosen for the current study. In addition, as a second search approach, we added studies found by a manual search of the included studies' reference lists. Included are articles on the genus Lindera that discuss traditional applications, essential oils, and biological activities. Articles that were discussed about traditional uses, essential oils, and their biological activities of *Lindera* were included together.

The following criteria were taken into consideration when including articles, which are original; journal articles are the only type of publications accepted, only articles written in English are permitted, the chemical composition of essential oils must be presented together, and their biological activity must be discussed in articles. The following were used as the exclusion criteria, which is the publications did not include the search terms in the title and abstract, incomplete article text could not be retrieved, and the papers did not list the essential oils' chemical composition.

3. MEDICINAL USES OF THE GENUS *LINDERA*

Worldwide, herbal medicines are being used as complementary and alternative medicine to treat various health diseases related. Most of Lauraceae family are used to make timber for export. They are suited for making plywood and decorative projects like interior finishing, panelling, furniture, and cabinets. The bark of many species offers marketable qualities such as

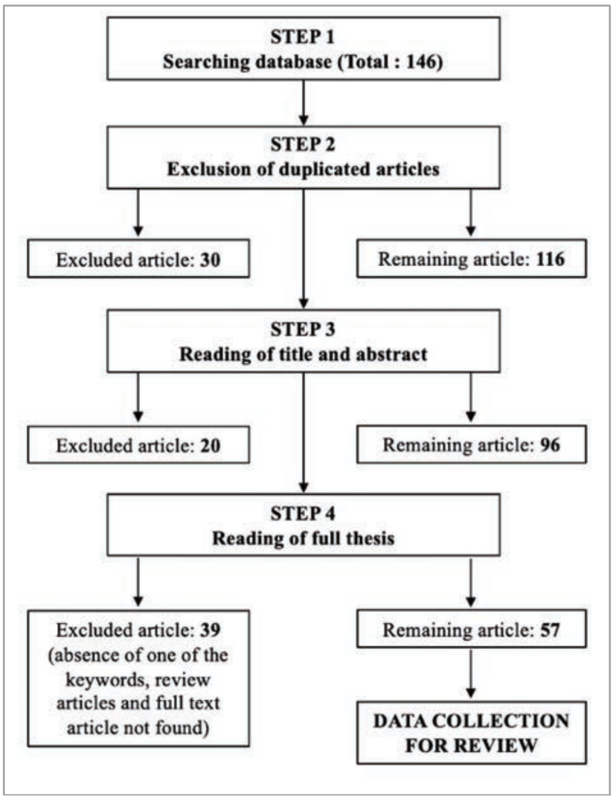

Figure 1 – PRISMA flow diagram of included studies

cinnamon [6]. Earlier studies reported that *Lindera* species are great for ornamental and economical use, as well as for their medicinal and therapeutic benefits. Different species of *Lindera* have been used as medicine to treat a wide range of conditions, such as gastrointestinal disorders, respiratory infections, and menstrual cramps [4]. Table I illustrates the medicinal uses of several *Lindera* species [17-33].

L. aggregata has been used in traditional Chinese medicine to treat a number of conditions, such as pain, inflammation, and gastrointestinal problems, while in Japan, this species has been used to treat cardiac, renal and rheumatic diseases [34]. Moreover, as an herbal medicine, *L. aggregata* is included in 24 formulae in Chinese Pharmacopoeia [35]. Meanwhile, *L. radix* is a very well-known species in Chinese culture, where the roots can be used to warm the kidneys by promoting blood circulation to lessen discomfort and relieve congestion [36]. In addition, in Taiwanese culture, the root parts of *L. akoensis* were used to treat trauma and inflammation [37]. Besides, the leaves of *L. obtusiloba* are traditionally consumed as both tea and food that traditionally used for restoring blood stasis and inflammatory disorders [38], whereas the bark of *L. obtusiloba* is used to treat bruises and throat congestion [39]. In another report, the leaves of *L. obtusiloba* could be used as an agent to suppress mucus hypersecretion, as it contains limonene that was known to be effective in reducing allergic airway inflammation [40]. Furthermore, the roots, bark, and twigs of *L. umbellata* have beneficial effects on gastric ulcer, abdominal pain, cholera, and beriberi, and its volatile oil was found to have antispasmodic effects [36]. Overall, the health benefits of *Lindera* are mainly attributed to its diverse bioactive constituents, which may contribute to its multiple health functions.

4. CHEMICAL COMPOSITIONS OF *LINDERA* ESSENTIAL OILS

In previous studies, thirteen *Lindera* species were described on the composition of the essential oils [41-57]. These were *L. chunii* [41], *L. communis* [42], *L. erythrocarpa* [23,43], *L. fragrans* [25], *L. glauca* [29, 44-47], *L. melissifolia* [48], *L. nacusua* [49], *L. neesiana* [31], *L. obtusiloba* [50-52], *L. pipericarpa* [53], *L. pulcherrima* [27,54], *L. strychnifolia* [55,56], and *L. umbellate* [33,57]. Most of *Lindera* species were reported mainly from China (13 studies), followed by Korea (5 studies), India (3 studies), whereas Vietnam, Japan, USA, Nepal, and Malaysia each were reported in one study. Table II shows the details of the reported *Lindera* essential oils, comprising various species, localities, plant parts, total components, percentage yield, and several major components.

Analysis of the chemical components identified in *Lindera* essential oils shows that the oil consists of

Table I – Medicinal uses of several *Lindera* species

Species	Traditional uses
L. aggregata	Remedy for rheumatic, cardiac, and renal illnesses [6]
	Treat conditions affecting the digestive system, metabolism, inflammation, and urinary system [17]
	Used as nutritional supplements to prevent liver damage and decrease cholesterol [17]
L. akoensis	Used to treat stomach pain, fever, respiratory infections, headaches, migraines, and reducing inflammation or swelling [18]
	Used in Taiwanese folk therapy for inflammation [18]
L. angustifolia	Relieve swelling caused by contusions, rheumatic pain, and stomachaches [19]
	Used to treat carminative diuretics, and pain relievers especially in nervous headache and migraine [20]
	Used to treat several gastrointestinal, nervous, and rheumatic disorders [21]
L. erythrocarpa	Used to treat multiple cardioprotective and cancerous disorders [22]
	Treating digestive disorders, thirst, pain, and neuralgia [23]
	Treat indigestion in folk medicine [24]
	Used to treat diabetic properties and breast cancer [6]
L. fragrans	Acts as an effective barrier that prohibits mosquitoes from biting [25]
	Used to treat rheumatic numbness and low back pain [25]
	Remedy for bad breath [26]
	Treat depressive-like behaviours that prolonged mild stress caused [24]
L. pulcherrima	Used as spice for the remedy of cold, fever, and cough [27]
	Treat intestinal worms and cure sores [27]
L. radix	Used in pelvic inflammatory disease [28]
L. glauca	Treat several kinds of stomach and heart discomfort problems [29]
	Used to treat rheumatoid arthritis, extravasation, and contusion [29]
L. neesiana	To treat indigestion, gastric disorders, constipation and intestinal issues [30]
	Eliminate intestinal parasitic worms like round and tape worms [31]
L. obtusiloba	Treatment for type II diabetes by lowering blood glucose levels as well as improve blood circulation, inflammation, fever, and abdominal pain [6]
L. umbellata	Effective treatment in relation properties [32]
	To treat neuralgia, stiff neck, and back pain [33]

several groups of components, which are monoterpene hydrocarbons, oxygenated monoterpenes, sesquiterpene hydrocarbons, and oxygenated sesquiterpenes. The essential oil of *L. obtusiloba* and *L. glauca* has received the most attention and has been widely investigated. The root oil of *L. glauca* gave the highest total components with 87 components (98.6%) [45], followed by the fruits oil of *L. obtusiloba*, with 78 components (98.8%) [52]. Meanwhile, the highest yield was given by the leaf oil of *L. obtusiloba* which gave 4.23% [51].

β-Caryophyllene, a sesquiterpene, was found as the most reported major component and can be found in the leaf oil of *L. communis* [42], *L. erythrocarpa* [43], *L. fragrans* [29], *L. glauca* [45], L. nacusua 49], *L. obtusiloba* [51], *L. pipericarpa* [53], and *L. pulcherrima* [54]. Another sesquiterpenes were also presented in high amounts such as viridiflorene, germacrene B [41], β-cadinene [41,50], δ-cadinene [41,50], α-humulene [43], germacrene A [29], aromadendrene, γ-cadinene [46], and β-selinene [55,56]. Meanwhile, oxygenated sesquiterpenes were also documented in high amounts such as α-cadinol, globulol, and t-cadinol, which were reported from the stem and leaf oils of

Table II – Major components identified in *Lindera* essential oils

Species	Locality (Part)	Total, %	Yield, %	Group, %	Major components (%)
L. chunii	China (Flowers)	37, 95.4	0.59	SH, 59.1	Viridiflorene (14.6%), β-cadinene (9.5%), globulol (6.3%), germacrene B (6.2%), t-cadinol (5.4%) [41]
	China (Leaves)	34, 96.2	0.46	SH, 59.1	Germacrene B (6.2%), globulol (11.6%), ledol (10.2%), γ-muurolene (4.4%) [41]
	China (Stems)	37, 96.4	0.06	OS, 52.1	α-Cadinol (8.6%), globulol (7.7%), t-cadinol (7.3%), δ-cadinene (6.5%) [41]
L. communis	China (Leaves)	23, NM	NM	NM	Spathulenol (22.5%), endo-1,3,3-trimethyl-2-norbornanol (10.0%), β-caryophyllene (6.7%) [42]
L. erythrocarpa	Korea (Leaves)	15, 63.7	0.07	NM	Nerolidol (18.7%), β-caryophyllene (14.4%), α-humulene (7.7%), germacrene D (4.8%), α-pinene (4.47%) [23]
	Korea (Leaves)	31, NM	NM	NM	Nerolidol (26.9%), β-caryophyllene (13.2%), methyl cinnamate (8.5%), α-humulene (8.4%), geranyl acetate (7.8%) [43]
L. fragrans	China (Leaves)	62, 76.4	NM	SH, 47.8	Spathulenol (27.6%), ledol (6.8%), β-caryophyllene (4.0%) [29]
L. glauca	China (Fruit)	48, 95.7	NM	MH, 56.9	(*E*)-β-Ocimene (41.5%), α-copaene (13.1%), δ-cadinene (6.2%) [29]
	China (Fruit)	70, 98.6	1.9	MH, 56.6	(*E*)-β-Ocimene (30.5%), β-caryophyllene (4.8%), δ-guaiene (4.7%) [44]
	China (fruit)	87, 73.9	0.6	SH, 40.0	(*E*)-β-Ocimene (12.9%), α-pinene (4.0%), β-caryophyllene (3.7%), cadina-1(10),4-diene (3.4%), camphene (2.5%) [45]
	China (fruit)	72, 88.6	1.2	MH, 57.7	(*E*)-β-Ocimene (37.4%), β-caryophyllene (3.7%), myrcene (3.5%) [45]
	China (fruit)	74, 87.2	1.4	MH, 44.7	(*E*)-β-Ocimene (30.3%), α-copaene (12.7%) [45]
	China (Fruits)	54	NM	NM	*N*-Carproic acid (25.3%), germacrene A (10.7%), *n*-dodecanole acid (10.0%), epishyobunol acetate (7.2%) [29]
	China (Fruits)	54	NM	NM	*N*-Carproic acid (25.3%), germacrene A (10.7%), *n*-dodecanole acid (10.0%), epishyobunol acetate (7.2%), β-caryophyllene (5.44%) [29]
	China (Leaves)	41, 87.5	0.32	MH, 46.5	β-Phellandrene (19.0%), myrcene (17.9%), aromadendrene (17.1%), γ-cadinene (10.1%), (*E*)-β-ocimene (9.1%) [46]
	Vietnam (Leaves)	34, 90.0	0.21	SH, 54.1	β-Caryophyllene (29.2%), α-humulene (18.0%), (*E*)-β-caryophyllene (14.6%), humulene epoxide II (5.3%), spathulenol (4.6%) [47]
	China (Fruit)	15 56.6	1.91	MH	(*E*)-β-Ocimene (30.5%), β-caryophyllene (5.1%), δ-guaiene (5.0%) [44]
L. melissifolia	USA (Fruit)	35, 86.7	NM	NM	Sabinene (66.2%), (*E*)-β-ocimene (12.9%), α-phellandrene (4.1%) [48]
L. nacusua	China (Leaves)	22, 64.4	NM	SH, 42.5	β-Caryophyllene (8.7%), hexahydrofarnesyl acetone (6.8%), β-selinene (5.0%), neo-phytadiene (4.5%), palmitic acid (4.4%) [49]
L. neesiana	Nepal (Fruit)	40, 86.0	NM	NM	(*Z*)-Citral (15.0%), (*E*)-citral (11.8%), α-copaene (8.7%), citronellal (6.7%) [31]

Table II (continue)

L. obtusiloba	Korea (Leaves)	25, 65.7	0.25	NM	δ-Cadinene (13.8%), limonene (10.2%), β-eudesmol (10.0%), hedycaryol (6.7%), α-pinene (5.7%), bornyl acetate (5.6%) [50]
	Korea (Leaves)	27, 67.8	4.23	NM	β-Caryophyllene (32.1%), α-copaene (31.4%), nerolidol (6.8%), β-farnesene (4.1%) [51]
	Korea (Fruit)	70, 83.7	NM	MH	Camphene (18.4%), α-thujene (13.8%), limonene (12.8%), linalyl acetate (12.5%), dihydromyrcene (11.1%) [52]
	Korea (stems)	58, 87.3	NM	MH, 37.0	Limonene (11.7%), β-phellandrene (7.7%), *tert*-butyl benzene (5.4%), santorina alcohol (5.0%), 1(10)*E*,5*E*-germacradien-4-ol (4.0%) [52]
	Korea (roots)	70, 80.8	NM	MH, 27.4	Limonene (6.7%), linalyl acetate (6.2%), camphene (5.1%), β-phellandrene (5.0%), 1-decyne (4.7%) [52]
	Korea (stems)	77, 89.1	NM	MH, 29.5	Linalyl acetate (12.5%), limonene (11.4%), dihydromyrcene (3.9%), β-phellandrene (3.8%), elema-1,3,11(13)-trien-12-ol (3.6%) [52]
	Korea (roots)	78, 98.8	NM	MH, 31.8	Linalyl acetate (13.0%), limonene (12.8%), β-phellandrene (4.6%), cyclododecanone (4.1%) [52]
	Korea (fruits)	70, 93.1	NM	MH, 67.8	Camphene (18.4%), α-thujene (13.8%), limonene (13.4%), β-myrcene (9.2%), α-phellandrene (3.8%) [52]
	Korea (leaves)	78, 87.8	NM	MH, 37.4	Dihydromyrcene (11.1%), germacrene B (7.5%), limonene (5.5%), α-eudesmol (4.3%), 2,2-bis(prop-2-enoxy-methyl)-butan-1-ol (3.87%) [52]
L. pipericarpa	Malaysia (Leaves)	22, 98.3	1.0	SH, 60.0	β-Caryophyllene (32.1%), α-copaene (31.4%), nerolidol (6.1%) [53]
	Malaysia (Wood)	17, 89.9	0.05	MH, 89.9	Limonene (55.4%), linalool (6.6%), geranial (6.7%), neral (5.1%) [53]
L. pulcherrima	India (Leaves)	26, 98.2	NM	OS, 75.3	Furanodienone (49.1%), curzerenone (17.4%), furanosesquiterpenoid (5.2%), furanodiene (3.5%) [54]
	India (Leaves)	35, 97.5	1.12	OS, 89.1	Furanosesquiterpenoid (79.3%), furanodienone (46.6%), curzerenone (17.6%) [54]
	India (Leaves)	28, 83.2	NM	SH, 79.3	Furanodienone (46.6%), germacrene D (26.0%), curzerenone (17.6%), β-caryophyllene (5.4%), β-eudesmol (4.1%) [54]
L. strychnifolia	China (Leaves)	49, 94.9	0.36	OS, 65.9	Sesquithuriferol (35.9%), 14-oxy-α-muurolene (16.5%), 1,8-cineole (5.3%), β-selinene (4.6%) [55]
	China (Leaves)	51, 94.5	0.43	OS, 65.8	Sesquithuriferol (35.9%), 14-oxy-muurolene (16.4%), 1,8-cineole (5.3%), β-selinene (4.5%), δ-cadinene (3.8%) [56]
	China (Roots)	58, 91.4	0.31	OS, 39.5	(*E*)-β-Ocimene (10.2%), 1,8-cineole (8.4%), isoterpinolene (4.7%) [56]
L. umbellate	Japan (Leaves)	27, 89.9	NM	NM	Linalool (42.8%), 1,8-cineole (13.7%), β-myrcene (7.6%), limonene (7.6%) [57]
	Japan (Twigs)	14, 75.2	NM	NM	Linalool (65.7%), geranyl acetate (17.5%), limonene (5.2%) [33]
	Japan (Leaves)	20, 93.2	NM	NM	Linalool (42.8%), 1,8-cineole (13.7%), β-myrcene (7.6%), limonene [33]

NM-not mentioned; MH-monoterpene hydrocarbon; SH-sesquiterpene hydrocarbon; OS-oxygenated sesquiterpene

L. chunii [41]. Besides, nerolidol was reported dominantly in the leaf oil of *L. erythrocarpa* [23,43], whereas spathulenol in the leaf oil of *L. communis* [42] and *L. fragrans* [29].

In addition, limonene was also found as foremost in other *Lindera* species such as *L. pipericarpa* [53], *L. obtusiloba* [50], *L. obtusiloba* [52], and *L. umbellate* [33]. The highest percentage of limonene was reported from the leaf oil of *L. pipericarpa* which gave 55.4% of the total oil [53].

In another study, (*E*)-β-ocimene [29,44,45,56], β-phellandrene [46], (*Z*)-citral [31], camphene [52], and dihydromyrcene [52] were found as major components of monoterpenes in *Lindera* essential oils. Meanwhile, sabinene and linalool were found as primary components with great percentage in the fruit oil of *L. melissifolia* [48] and twig oil of *L. umbellate* [33], respectively.

According to the above-mentioned findings, the chemical variations between *Lindera* species may be caused by the various stages of development and the unique habitat in which the plant was taken. Furthermore, the chemical and biological variety of aromatic and medicinal plants is influenced by factors such as climatic circumstances, vegetation phase, and genetic changes [58]. Thus, these factors have an impact on the plant's biosynthetic pathways resulting in distinctive chemicals.

5. BIOLOGICAL ACTIVITIES

Many researchers are interested in discovering more about biological actives as it comprises a vast range of natural products with the potential to be used in medicine, agriculture, and industry. Bioactive compounds of *Lindera* essential oils have been reported to exhibit various biological activities as illustrated in Table III [59-68]. Most of the studies were focused on the anti-inflammatory and antibacterial properties of *Lindera* essential oils.

For anti-inflammatory activity, several different assays were used to determine the properties, such as in vitro, animal models, and clinical trials. In vitro assays were used to measure the nitric oxide (NO) production in the cell, in which the leaf and twig oils of *L. obtusiloba* showed a strong inhibition with IC_{50} values 0.8 and 8.7 μM, respectively [6]. Besides, *L. aggregata* oil also have significant inhibition of superoxide anion in human neutrophils, hence it is effective to act as anti-inflammatory agent [17]. Eucalyptol and linalool are major components of *Lindera* essential oils, which were reported to exhibit anti-inflammatory properties by lowering the production of inflammatory properties and blocking the activity of enzymes that cause inflammation [67]. For antibacterial activity, the root oil of *L. myrrha* may have a strong activity against *Enterococcus faecium*, *Staphylococcus aureus*, and *Acinetobacter baumannii*, whereas *L. pulcherrima* essential was found to exhibit a strong activity against *Salmonella*, *Pasturella multocida* and *Escherichia coli* [54].

According to a previous study, it is often the unique chemical combination rather than a single component that is responsible for any therapeutic activity. In

Table III – Biological activities of *Lindera* essential oils

Bioactivities	Essential oils	Description
Anti-allergic	*L. obtusiloba*	The leaf oil have strongly effective in decreasing airway hyper-responsiveness and mucus production in the lung tissue against *Streptococcus pneumoniae* [59]
		The root oil was reported to inhibit histamine release and pro-inflammatory cytokine production in mast cells with percentage inhibition 66.9% and 68.1%, respectively [60]
		The root oil was reported to have same role as gallic acid, where it can suppressed the release of histamine from mast cells to prevent itching [6]
		The leaf oil have significantly inhibited the expressions of IL-6 and TNF-α in mast cells to reduce allergic symptoms [60]
Anti-arthritic	*L. aggregata*	The leaf oil shown development of Treg cells through promoting fatty acid oxidation, thus it can controlling immune responses including rheumatoid arthritis with EC_{50} value 94% [61]
Antivirus	*L. aggregata*	The stem oil inhibit the fusion of HIV-1 infected with IC_{50} value 5.2 – 31.3 μM [61]
Antibacterial	*L. myrrha*	The root oil have strong activity against *Enterococcus faecium*, *Staphylococcus aureus*, and *Acinetobacter baumannii* with killing percentage 85.6%, 86.7%, and 92.1%, respectively [54]
	L. pulcherrima	The essential oil revealed a strong activity against *Salmonella, Pasturella multocida* and *Escherichia coli* with IC_{50} value 19.0, 18.0 and 10.8 μL, respectively [54]
	L. gluca	The fruit oil have strong activity against *Shigella flexneri* with the inhibition zone diameter 25.4 nm [44]
Anticancer	*L. aggregata*	The root oil have exhibited human colorectal cancer cells with IC_{50} value 6.48 μg/mL [62]
		The root oil exhibit the transforming growth factor (TGF)-β inhibitory activity with IC_{50} value 12.9 μg/mL [63]
		The root oil showed strongly inhibited against A549 cell lines and neuroprotective activity in SH-SY5Y cells [63]
		The root oil showed activity in human colon cancer cell line with IC_{50} value 9.80 μM [17]
Anti-inflammatory	*L. aggregata*	The root oil exhibited human neutrophils with IC_{50} value 7.45 μM [64]
		The essential oil displayed the significant inhibition of superoxide anion generation in human neutrophils with IC_{50} values 8.36 μM [64]
	L. akoensis	The aerial part oil have the ability to decrease the LPS-stimulated production of nitrite in RAW264.7 cell with IC_{50} value 38.3 μM [64]
	L. blume	The leaf oil showed strong inhibition in prostaglandins production in an A549 with IC_{50} value 0.82 μM [65]
	L. obtusiloba	The twig oil inhibited nitric oxide production with IC_{50} values 3.6–26.4 μM [6]
Antitumor	*L. gluca*	The essential oil showed weak activity against SMMC-7721 cell line with IC_{50} value 35.2 μM [66]
	L. strychnifolia	The essential oil showed activity against human esophageal cancer Eca-109 cell line with IC_{50} value 24.8 μg/mL [67]
Cytotoxicity	*L. glauca*	The twig oil showed strong activity against SK- MEL-2 and HCT-15 cell lines with IC_{50} values ranging from 9.9 to 12.2 μM [68]
	L. reflexa	The root oil showed the activity against MGC803 and SMMC-7721 cell lines with IC_{50} values 2.65 and 4.13 μM, respectively [66]
	L. strychnifolia	The essential oil has strong activity on liver cancer cells line and breast tumor cell line with IC_{50} values 2.85 and 3.47 μg/mL, respectively [55]

some cases, that biological activity of the essences from the aromatic plants studied may be attributable both to their major components and to the minor ones in the oils. Hence, the synergistic effects of active chemicals with other components of the essential oil should be taken into consideration [70].

6. CONCLUSION

This current review provides an overview of *Lindera* essential oils in medicinal uses, chemical composition, and biological activities. The *Lindera* essential oils revealed high amounts of β-caryophyllene, limonene, (*E*)-β-ocimene, α-copaene, α-pinene, β-phellandrene, nerolidol, globulol, and 1,8-cineole; which potentially contribute to the bioactivities such as anti-inflammatory, antibacterial and anticancer properties. However, the variation in the amount of its composition within the same species that were reviewed could be varied due to environmental and geographical factors. Hence, more pharmacological investigations should be done to unravel the full therapeutic ability of *Lindera* species. Preclinical analyses and clinical trials for essential oils are also required to evaluate the potential of essential oils from *Lindera* species for drug development. Lastly, it is hoped that within the information provided, it will help researchers in selecting species with an economic potential within a wide range of industries.

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