

# Chemical Composition and Biological Activities of Essential Oils in the Family Lauraceae: A Systematic Review of the Literature

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## Key words

Lauraceae,  $\beta$ -caryophyllene, 1,8-cineole, antioxidant, antimicrobial

received March 18, 2019

revised May 23, 2019

accepted May 28, 2019

## Bibliography

DOI <https://doi.org/10.1055/a-0943-1908>

Published online July 1, 2019 | *Planta Med* 2019; 85: 1054–1072 © Georg Thieme Verlag KG Stuttgart · New York | ISSN 0032-0943

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## ABSTRACT

The Lauraceae family is predominantly found in Asia and in the rainforests of the Americas, and consists mostly of aromatic trees. Being an essential oil producer, this family is used in the food, pharmaceutical, and cosmetic industries. This work presents a systematic review of the chemical composition and bioactivity of the essential oils from the Lauraceae family. Medline, Scielo, Web of Science, Lilacs, and Scopus were employed to identify articles published between 2000 and 2018, using “Lauraceae”, “essential oil”, and “biological activity” as key words. From 177 studies identified, 53 met the inclusion criteria. These studies indicated a predominance of the compounds  $\beta$ -caryophyllene and 1,8-cineole in Lauraceae species, and highlighted the antioxidant, antifungal, antibacterial, and anti-inflammatory activities. Essential oils extracted from this family thus have high potential for pharmacological applications.

## Introduction

Lauraceae, one of the most primitive families of plants, belongs to the Magnoliidae subclass and has a tropical and subtropical distribution, predominantly in Asia and the tropical forests of the Americas. With the exception of the *Cassytha* genus, composed of parasitic vines, the family comprises trees and shrubs [1,2]. The economic importance of this botanical family lies in that many species are used in industrial sectors such as the food, timber, pharmaceutical, and perfumery industries. Regarding its ethnobotany, Lauraceae species have been applied to multiple different pathologies. Salleh et al. [3] outlined several medicinal uses for the genus *Beilschmiedia*, such as in the treatment of infectious diseases, malaria, analgesic, gastrointestinal infections, female genital infections, and rheumatism, among others.

Regarding the secondary metabolites in Lauraceae, neolignans have significant chemotaxonomic potential [4]. The isoquinolinic

alkaloids are also widely representative of the family [5], as are essential oils (EOs) [6]. EOs are a mixture of active chemical substances with low molecular weight, some highly volatile, characterized by a strong odor, and are capable of providing flavor and/or aroma [7]. The composition of EOs includes a wide range of compounds, including terpene hydrocarbons, simple and terpene alcohols, aldehydes, ketones, phenols, esters, ethers, organic acids, and lactones [8]. Of these compounds, terpenes are the main constituent of EOs and their applications, including being the active ingredients in nanostructured systems to improve the physicochemical properties and/or achieve greater bioavailability in the controlled release of drugs [9].

The terpene group is derived from isopentenyl diphosphate (IDP). This substance comes from two different biosynthetic routes, both originating from glucose: mevalonate and desoxy-xylulose phosphate pathways [10]. Terpenes are classified according to the number of isoprene units in their structure: isoprenes or

hemiterpenes (5C), monoterpenes (10C), sesquiterpenes (15C), diterpenes (20C), sesterpenes (25C), triterpenes (30C), tetraterpenes (40C), and polysoprenoids, when there are more than 35 carbons [11]. In the Lauraceae family, there is a predominance of sesquiterpenes, mainly, sesquiterpene hydrocarbons [12]. The objective of this review involved surveying the chemical composition of EOs from species of Lauraceae, as well as their attributed bioactivity.

## Search Strategy

This systematic review was conducted through searches using Medline, Scielo, Web of Science, Lilacs, and Scopus in July 2018. The key words used were “Lauraceae”, “essential oil”, and “biological activity”, and articles were required to have been published during the period of 18 years between January 2000 and July 2018. Key words were used only in English. A manual search was performed in bibliographic references from the articles found.

The inclusion of articles considered the following criteria: (1) type of publication – original journal articles, (2) only articles in English, Portuguese, and Spanish, (3) articles must present the chemical composition of the essential oil, (4) articles must discuss biological activity, and (5) studies used both *in vivo* and *in vitro* assays.

As exclusion criteria, the following were used: (1) articles in languages apart from English, Portuguese, and Spanish, (2) review articles, (3) full text articles not found, (4) articles without one of the key words, (5) articles discussing a mixture of plants, and (6) articles that did not present the composition of the EOs.

The first step was to exclude duplicate articles. Titles and abstracts were then read and the inclusion and exclusion criteria were applied. All articles resulting from this stage were read in full and the inclusion and exclusion criteria were applied again. Following this step, we reached the articles chosen for the present study.

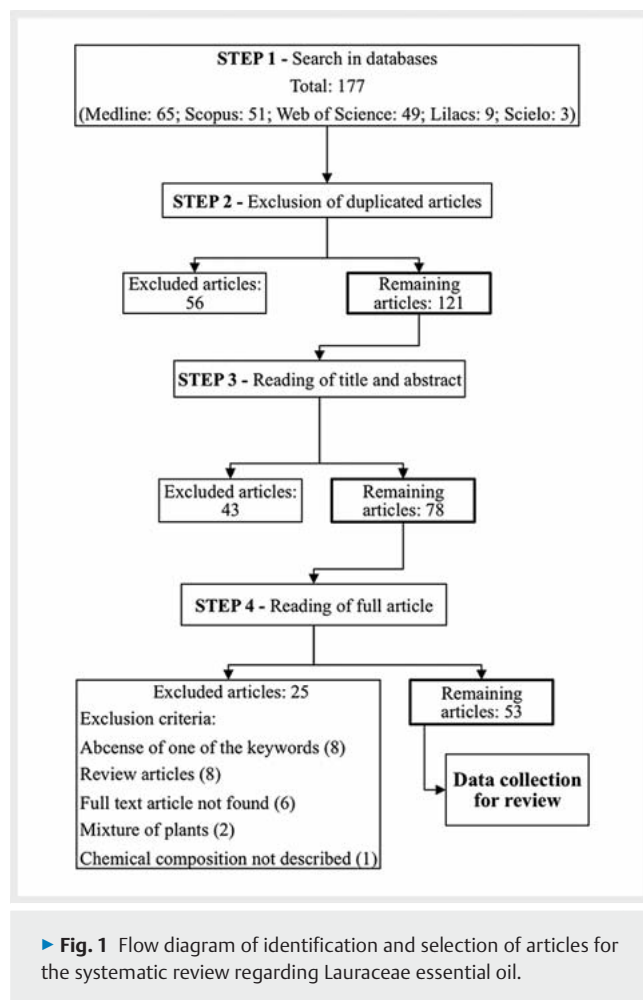
For data collection, a tool was elaborated with the following information: author, date, plant, major constituents, quantification of constituents, EO extraction method, constituent identification method, and biological activities.

## Results and Discussion

Based on the described criteria, 121 articles were selected after eliminating 56 duplicates. The analysis of titles and abstracts excluded 43 further articles, leaving 78 eligible articles, of which 25 were excluded after reading the full text version. Thus, 53 articles comprised the present study, written between 2002 and 2018. ► **Fig. 1** summarizes the selection process.

► **Table 1** presents data for each species with the respective chemical constituents and bioactivity. ► **Table 2** shows the chemical structure of the major compounds. ► **Fig. 2** displays the percentage of the major compounds found in the evaluated articles.

As shown in ► **Fig. 2**,  $\beta$ -caryophyllene and 1,8-cineole are the predominant components in the Lauraceae family. *trans*-Caryophyllene, a synonym of *E*-caryophyllene,  $\beta$ -caryophyllene, and *trans*- $\beta$ -caryophyllene, is a bicyclic sesquiterpene characterized by numerous EOs and its strong odor. It is applied commercially



in the food and cosmetic sectors as a flavoring, a fragrance fixer in perfumes, and in personal hygiene products [65]. Furthermore, this substance has demonstrated pharmacological potential by virtue of its anti-inflammatory [66], neuroprotective [67], anti-cancer, antioxidant, antimicrobial [68], and antinociceptive [69] activities, among others.

The bicyclic monoterpene 1,8-cineole, also known as eucalyptol, presents different pharmacological activities, and studies on this compound mostly focus on the therapeutic treatment of severe pulmonary diseases. Clinical studies have demonstrated improvements in the treatment of chronic obstructive pulmonary disease using 1,8-cineole when compared to a placebo group [70]. Another study suggested anti-inflammatory activity of this monoterpene in asthma as a mucolytic agent in upper and lower airway diseases [71]. Other research corroborates these results by reporting mucolytic, bronchodilator, and anti-inflammatory activities [72–74].

Tied in third place are the substances linalool,  $\delta$ -cadinene, and  $\alpha$ -pinene. Linalool, an acyclic monoterpene, is a major component of EOs from different aromatic species. Similar to  $\beta$ -caryophyllene, linalool is used in the food and cosmetic industries, especially in perfumes and other general cosmetics [75]. Among its described utilities are that it is an antidepressive [76], is neuroprotective [77], and can prevent Alzheimer’s disease [78]. Regarding the

► **Table 1** Chemical composition and bioactivity of EOs from the Lauraceae family in the studies selected through this systematic review.

Plant species (part used)	Major compounds	Extraction method	Separation/identification method	Bioactivity	Reference
<i>Aniba canellilla</i> <sup>a</sup> (leaf and fine stems)	(01) 1-Nitro-2-phenylethane (91.8%) (02) $\beta$ -caryophyllene (1.6%) (03) Selin-11-en-4- $\alpha$ -ol (1.3%)	Hydrodistillation	GC-MS/comparison of relative retention index to literature	Antioxidant	[13]
<i>Aniba canellilla</i> <sup>a</sup> (trunk/Wood)	(01) 1-Nitro-2-phenylethane (92.1%) (05) Methyl Eugenol (4.3%) (06) Eugenol (1.2%)	Hydrodistillation	GC-MS/comparison of relative retention index to literature	Antioxidant Toxic against brine shrimp	[13]
<i>Aniba canellilla</i> (bark/Wood)	(01) 1-Nitro-2-phenylethane (90.3%) (03) Selin-11-en-4- $\alpha$ -ol (3.5%) (05) Methyl Eugenol (2.0%)	Hydrodistillation	GC-MS/comparison of relative retention index to literature	Antioxidant	[13]
<i>Aniba canellilla</i> <sup>a</sup> (leaf)	(01) 1-Nitro-2-phenylethane (88.9%) (02) $\beta$ -Caryophyllene (4.21%) (07) $\beta$ -Phellandrene (0.8%)	Hydrodistillation	GC-FID GC-MS/comparison of relative retention index to literature or WILEY data system library	Antifeishmanial Cytotoxic Toxic against brine shrimp	[14]
<i>Aniba rosaeodora</i> <sup>b</sup>	(04) Linalool (81.27%) (08) $\alpha$ -Terpineol (4.78%) (09) <i>trans</i> -Linalool oxide (2.10%)	Commercial sample	GC GC-MS/comparison of relative retention index to literature or WILEY data system library	Antifungal	[15]
<i>Beilschmiedia kunstleri</i> (leaf)	(02) $\beta$ -Caryophyllene (12.1%) (10) Germacrene B (11.2%) (11) $\alpha$ -Cadinol (10.4%)	Hydrodistillation	GC GC-MS/comparison of relative retention index to literature or WILEY data system library	Antioxidant Antibacterial Antifungal Anticholinesterase Anti-tyrosinase Anti-inflammatory	[16]
<i>Beilschmiedia kunstleri</i> (bark)	(12) $\delta$ -Cadinene (13.4%) (02) $\beta$ -Caryophyllene (10.6%) (11) $\alpha$ -Cadinol (9.0%)	Hydrodistillation	GC GC-MS/comparison of relative retention index to literature or WILEY data system library	Antioxidant Antibacterial Antifungal Anticholinesterase Anti-tyrosinase Anti-inflammatory	[16]
<i>Beilschmiedia madang</i> (leaf)	(12) $\delta$ -Cadinene (17.0%) (13) $\alpha$ -Cubebene (11.3%) (02) $\beta$ -Caryophyllene (10.3%)	Hydrodistillation	GC-MS/comparison of relative retention index to literature or WILEY data system library	Antioxidant Antibacterial Antifungal Anticholinesterase Anti-tyrosinase	[17]
<i>Beilschmiedia madang</i> (bark)	(12) $\delta$ -Cadinene (20.5%) (13) $\alpha$ -Cubebene (15.6%) (11) $\alpha$ -Cadinol (10.6%)	Hydrodistillation	GC-MS/comparison of relative retention index to literature or WILEY data system library	Antioxidant Antibacterial Antifungal Anticholinesterase Anti-tyrosinase	[17]

cont.

▶ Table 1 Continued						
Plant species (part used)	Major compounds	Extraction method	Separation/identification method	Bioactivity	Reference	
<i>Beilschmiedia mainiyai</i> (bark)	(14) $\beta$ -Eudesmol (17.5%) (15) Caryophyllene oxide (12.8%) (16) $\beta$ -Panasinene (11.6%)	Hydrodistillation	GC GC-MS/comparison of relative retention index to literature or WILEY data system library	Antioxidant Antibacterial Antifungal Anticholinesterase Anti-tyrosinase Anti-inflammatory	[16]	
<i>Beilschmiedia mainiyai</i> (leaf)	(14) $\beta$ -Eudesmol (24.1%) (15) Caryophyllene oxide (11.0%) (16) $\beta$ -Panasinene (10.2%)	Hydrodistillation	GC GC-MS/comparison of relative retention index to literature or WILEY data library	Antioxidant Antibacterial Antifungal Anticholinesterase Anti-tyrosinase Anti-inflammatory	[16]	
<i>Beilschmiedia miersii</i> (leaf and stem bark)	(17) Sarisan (45.8%) (05) Eugenol methyl ether (27.7%) (18) Safrole (5.8%)	Hydrodistillation	GC-MS/comparison of relative retention index to literature or NIST library	Antimicrobial activity	[18]	
<i>Beilschmiedia penangiana</i> (leaf)	(12) $\delta$ -Cadinene (28.7%) (19) Germacrene D (20.7%) (02) $\beta$ -Caryophyllene (10.4%)	Hydrodistillation	GC GC-MS/comparison of relative retention index to literature or WILEY data library	Antioxidant Antibacterial Antifungal Anticholinesterase Anti-tyrosinase Anti-inflammatory	[16]	
<i>Beilschmiedia penangiana</i> (bark)	(12) $\delta$ -Cadinene (17.5%) (19) Germacrene D (14.6%) (02) $\beta$ -Caryophyllene (12.6%)	Hydrodistillation	GC GC-MS/comparison of relative retention index to literature or WILEY data library	Antioxidant Antibacterial Antifungal Anticholinesterase Anti-tyrosinase Anti-inflammatory	[16]	
<i>Beilschmiedia pulverulenta</i> <sup>a</sup>	(06) Eugenol (45.3%) (20) Eugenol acetate (5.6%) (21) $\alpha$ -Ylangene (3.6%)	Hydrodistillation	GC-MS/comparison of relative retention index to literature or WILEY data library	Antioxidant Antibacterial Antifungal Anticholinesterase Anti-tyrosinase Anti-inflammatory	[19]	
<i>Cinnamomum cassia</i> (bark)	(22) 2-Hydroxycinnamaldehyde <sup>c</sup> (23) Cinnamaldehyde <sup>c</sup> (24) Coumarin <sup>c</sup>	Steam distillation	GC/not reported	Cytotoxic <i>in vitro</i> and <i>in vivo</i> hepatic function	[20]	
<i>Cinnamomum cassia</i> <sup>a</sup>	(25) <i>cis</i> -2-Methoxycinnamic acid (43.06%) (23) Cinnamaldehyde (42.37%) (26) <i>o</i> -Methoxycinnamaldehyde (5.11%)	Steam distillation	GC-MS/comparison the spectra with NIST	Anti-tyrosinase Anti-melanogenic	[21]	

cont.

▶ Table 1 Continued

Plant species (part used)	Major compounds	Extraction method	Separation/identification method	Bioactivity	Reference
<i>Cinnamomum cassia</i> <sup>a</sup>	(23) Cinnamaldehyde (87.23%) (27) Hydrocinnamaldehyde (1.69%) (28) Cinnamyl alcohol (1.36%)	Commercial sample (hydrodistillation)	- <sup>d</sup>	Antifungal	[22]
<i>Cinnamomum camphora</i> (leaf)	(29) Camphor (18.48%) (30) Eucalyptol (16.46%) (04) Linalool (11.58%)	Hydrodistillation	GC/GC-TOFMS	Insecticidal Repellent	[23]
<i>Cinnamomum camphora</i> (twig)	(30) Eucalyptol (17.21%) (29) Camphor (13.17%) (31) 3,7-Dimethyl-1,3,7-octatriene (11.47%)	Hydrodistillation	GC/GC-TOFMS	In vitro toxicity Repellent	[23]
<i>Cinnamomum camphora</i> (seed)	(30) Eucalyptol (20.90%) (05) Methyl Eugenol (19.98%) (04) Linalool (14.66%)	Hydrodistillation	GC/GC-TOFMS	In vitro toxicity Repellent	[23]
<i>Cinnamomum cassia</i> <sup>b</sup>	(24) <i>trans</i> -Cinnamaldehyde (85.06%) (27) <i>o</i> -Methoxy-cinnamaldehyde (8.79%) (32) <i>cis</i> -Cinnamaldehyde (1.33%)	Commercial sample (hydrodistillation)	GC-MS/comparison the spectra with NIST	Antibacterial Fungicidal	[24]
<i>Cinnamomum cassia</i> (twig)	(23) ( <i>E</i> )-Cinnamaldehyde (79.39%) (33) Aromatic turmerone (4.68%) (34) 11-Oxatetracyclo[5.3.2.0(2,7).0(2,8)]dodecan-9-one (3.67%)	Hydrodistillation	GC-MS/comparison the spectra with NIST	Antinociceptive Anti-inflammatory ( <i>in vivo</i> )	[25]
<i>Cinnamomum glanduliferum</i> <sup>b</sup>	(30) 1,8-Cineole (41.4%) (35) $\alpha$ -Pinene (20.3%) (08) $\alpha$ -Terpineol (9.4%)	- <sup>d</sup>	GC-MS/not reported	Antibacterial	[26]
<i>Cinnamomum glanduliferum</i> (bark)	(30) Eucalyptol (65.87%) (36) Terpinen-4-ol (7.57%) (08) $\alpha$ -Terpineol (7.39%)	Hydrodistillation	GC-FID GC-MS/comparison the spectra with WILEY/NIST	Antimicrobial In vitro cytotoxicity	[27]
<i>Cinnamomum osmophloeum</i> (leaf)	(30) 1,8-Cineole (17%) (37) Santolina triene (14.2%) (38) Spathulenol (15.7%)	Hydrodistillation	GC-MS/comparison the spectra with WILEY	Anti-inflammatory	[28]
<i>Cinnamomum tamala</i> (leaf)	(23) Cinnamaldehyde (44.898%) (39) <i>trans</i> -Cinnamyl acetate (25.33%) (40) Ascabin (15.25%)	Hydrodistillation	GC-MS/comparison of relative retention index to literature	Antidiabetic Antioxidant Hypolipidemic	[29]
<i>Cinnamomum tonduzii</i> <sup>b</sup>	(35) $\alpha$ -Pinene (41.4%) (41) $\beta$ -Pinene (25.1%) <sup>e</sup>	Hydrodistillation	GC-MS/comparison the spectra with NIST	Cytotoxic Antibacterial Toxicity against brine shrimp	[30]
<i>Cinnamomum verum</i> (bark)	(23) <i>t</i> -Cinnamaldehyde (4.3%) (30) Eucalyptol (0.32%)	Hydrodistillation	GC-MS/comparison the spectra with NIST	Antibacterial	[31]

cont.

▶ Table 1 Continued						
Plant species (part used)	Major compounds	Extraction method	Separation/identification method	Bioactivity	Reference	
<i>Cinnamomum verum</i> <sup>b</sup>	(40) Benzyl benzoate <sup>c</sup> (20) Eugenol acetate <sup>c</sup> (06) Eugenol <sup>f</sup>	- <sup>d</sup>	GC/not reported	Inhibition of listeriolysin O and phosphatidylcholine-specific production in <i>Listeria monocytogenes</i>	[32]	
<i>Cinnamomum verum</i> (caule)	(23) (E)-Cinnamaldehyde (81.52%) (06) Eugenol (16.68%) (02) β-Caryophyllene (1.19%)	Commercial sample	GC-MS/comparison of relative retention index to literature and WILEY/NIST data library	Inhibitory activity against <i>Trypanosoma cruzi</i>	[33]	
<i>Cinnamomum verum</i> (leaf)	(40) Benzyl benzoate (65.4%) (04) Linalool (5.4%) (23) (E)-Cinnamaldehyde (4.0%)	Hydrodistillation	GC-MS/comparison of relative retention index to literature and NIST data library	Acaricidal	[34]	
<i>Cinnamomum zeylanicum</i> (bark)	(23) (E)-Cinnamaldehyde (78.5%) (26) 2-Methoxy-cinnamaldehyde (9.6%) (39) Cinnamyl-acetate (3.1%)	Commercial sample	GC-MS/comparison of relative retention index to literature and WILEY/NIST data library	Repellent	[35]	
<i>Cinnamomum zeylanicum</i> (leaf)	(06) Eugenol (73.27%) (02) β-Caryophyllene (5.38%) (04) Linalool (3.31%)	Commercial sample hydrodistillation	GC-MS/comparison of relative retention index to literature and NIST data library	Antibacterial	[36]	
<i>Cinnamomum zeylanicum</i> (bark)	(23) (E)-Cinnamaldehyde (59.42%) (39) Cinnamyl acetate (15.04%) (07) β-phellandrene (3.78%)	Commercial sample	GC-MS/not reported	Anti-inflammatory	[37]	
<i>Cinnamomum zeylanicum</i> (leaf)	(23) (E)-Cinnamaldehyde (63.07%) (39) Cinnamylacetate (6.86%) (07) β-Phellandrene + (31) 1,8-cineol (4.29%)	Commercial sample	GC-MS/not reported	Antimicrobial	[38]	
<i>Cinnamomum zeylanicum</i> (bark)	(23) (E)-Cinnamaldehyde (54.54%) (39) Cinnamyl acetate (6.87%) (07) β-Phellandrene (5.23%)	Commercial sample	GC-FID/not reported	Weak activation of AhrR – AhrR full agonist; induction of CYP1A1 mRNA	[39]	
<i>Cinnamomum zeylanicum</i> (leaf)	(06) Eugenol (87.3%) (02) β-Caryophyllene (1.9%) (42) α-Phellandrene (1.9%) <sup>e</sup>	Commercial sample	GC-MS /comparison of relative retention index to literature and WILEY/NIST data library	Antibacterial	[40]	
<i>Cinnamomum zeylanicum</i> (bark)	(23) <i>trans</i> -Cinnamaldehyde (97.7%) (12) δ-Cadinene (0.9%) (21) α-Copaene (0.8%) <sup>e</sup>	Commercial sample	GC-MS /comparison of relative retention index to literature and WILEY/NIST data library	Antibacterial	[40]	

cont.

► Table 1 Continued

Plant species (part used)	Major compounds	Extraction method	Separation/identification method	Bioactivity	Reference
<i>Cryptocarya alba</i> (leaf)	(36) 1-Terpinen-4-ol (28.19%) (43) $\beta$ -Terpinene (23.08%) (30) Eucalyptol (18.9%)	Steam distillation	GC-MS/comparison of relative retention index to literature and NIST data library	Antibacterial Antifungal	[41]
<i>Endlicheria citriodora</i> (leaf)	(44) Methyl geranate (93.7%) (04) Linalool (2.8%) (45) Geranic acid (1.9%)	Hydrodistillation	GC-FID GC-MS/comparison of relative retention index to literature, WILEY data library and NMR	Cytotoxic Tyrosinase inhibitor Antioxidant	[42]
<i>Endlicheria citriodora</i> (branches)	(44) Methyl geranate (95.1%) (04) Linalool (1.2%)	Hydrodistillation	GC-FID GC-MS/comparison of relative retention index to literature, WILEY data library and NMR	Cytotoxic Tyrosinase inhibitor Antioxidant	[42]
<i>Laurus nobilis</i> <sup>a,b</sup>	(30) 1,8-Cineole (16.3%) (46) $\alpha$ -Terpinyl acetate (16.6%) (05) Methyl eugenol (11%)	Hydrodistillation	GC-MS/comparison of relative retention index to literature	Antibacterial Antifungal	[43]
<i>Laurus nobilis</i> <sup>a,b</sup>	(30) 1,8-Cineole (17.6%) (04) Linalool (13.4%) (46) $\alpha$ -Terpinyl acetate (10.6%) (05) Methyl eugenol (10.6%)	Supercritical fluid	GC-MS/comparison of relative retention index to literature	Antibacterial Antifungal	[43]
<i>Laurus nobilis</i> <sup>b</sup>	(30) 1,8-Cineol (44.72%) (46) $\alpha$ -Terpinyl acetate (12.95%) (47) Sabinene (12.82%)	Hydrodistillation	GC-MS/comparison the spectra with WILEY/NIST	Antibacterial Antioxidant	[44]
<i>Laurus nobilis</i> <sup>b</sup>	(30) Eucalyptol (27.2%) (46) $\alpha$ -Terpinenyl acetate (10.2%) (04) Linalool (8.4%)	Hydrodistillation	GC-MS/comparison of relative retention index to literature and WILEY data library	Antibacterial Antioxidant	[45]
<i>Laurus nobilis</i> <sup>b</sup>	(30) 1,8-Cineole (60.72%) (49) $\alpha$ -Terpinene (12.53%) (47) Sabinene (12.12%)	Steam distillation	GC-MS/comparison the spectra with WILEY	Antibacterial	[46]
<i>Laurus nobilis</i> (leaf)	(30) 1,8-Cineole (35.15%) (46) 1-p-Menthen-8-ethyl acetate (13.52%) (04) Linalool (7.08%)	- <sup>d</sup>	GC-MS/comparison of relative retention index to literature and WILEY data library	Antioxidant Antiproliferative	[47]
<i>Laurus nobilis</i> (seed)	(48) $\beta$ -ocimene (21.83%) (30) 1,8-Cineole (9.43%) (35) $\alpha$ -Pinene (3.67%)	- <sup>d</sup>	GC-MS/comparison of relative retention index to literature and WILEY data library	Antioxidant Antiproliferative	[47]

cont.

▶ Table 1 Continued						
Plant species (part used)	Major compounds	Extraction method	Separation/identification method	Bioactivity	Reference	
<i>Laurus nobilis</i> <sup>b</sup>	(30) 1,8-Cineole (41.86%) (47) Sabinene (9.12%) (35) $\alpha$ -Pinene (7.2%)	Commercial sample	GC GC-MS/comparison of relative retention index to literature or WILEY data system library	Antifungal	[15]	
<i>Laurus nobilis</i> (leaf)	(30) 1,8-Cineole (31.9%) (47) Sabinene (12.2%) (50) <i>trans</i> -Sabinene hydrate (10.2%)	Hydrodistillation	GC/FID GC-MS/comparison of relative retention index to literature and WILEY/NIST data library	Antimicrobial Reduction of ADCY1 expression	[48]	
<i>Laurus nobilis</i> (leaf)	(30) Eucalyptol (45.51%) (46) Terpinyl acetate (7.99%) (47) Sabinene (7.98%)	Commercial sample	GC-FID/not reported	Toxic <i>in vitro</i>	[39]	
<i>Licaria canella</i> (leaf)	(40) Benzyl benzoate (69.7%) (21) $\alpha$ -Copaene (4.99%) (42) $\alpha$ -Phellandrene (4.20%) <sup>b</sup>	Hydrodistillation	GC-FID GC-MS/comparison of relative retention index to literature or WILEY data system library	Antileishmanial Cytotoxic Toxic against brine shrimp	[14]	
<i>Licaria rigida</i> <sup>a</sup> (leaf)	(51) 6-Methoxy-elemicin (51.86%) (02) $\beta$ -Caryophyllene (15.32%) (03) Selin-11-en-4 $\alpha$ -ol (9.68%)	Hydrodistillation	GC-MS/identified by reference standards	Antioxidant Antibacterial Cytotoxic	[49]	
<i>Licaria rigida</i> <sup>a</sup> (twig)	(51) 6-Methoxy-elemicin (63.31%) (03) Selin-11-en-4 $\alpha$ -ol (23.99%) (36) Terpinen-4-ol (2.31%)	Hydrodistillation	GC-MS/identified by reference standards	Antioxidant Antibacterial Cytotoxic	[49]	
<i>Licaria rigida</i> <sup>a</sup> (branch)	(51) 6-Methoxy-elemicin (39.55%) (03) Selin-11-en-4 $\alpha$ -ol (21.82%) (36) Terpinen-4-ol (9.97%)	Hydrodistillation	GC-MS/identified by reference standards	Antioxidant Antibacterial Cytotoxic	[49]	
<i>Lindera neesiana</i> (fruits)	(57) Z-citral (15.08%) (58) E-citral (11.89%) (30) Eucalyptol (8.75%)	Hydrodistillation	GC-MS/identified by NMR	Antibacterial Antifungal	[50]	
<i>Litsea cubeba</i> <sup>b</sup>	(57 + 58) Citral (neral + geranial) (69.8%) (59) Limonene (12.7%) (04) Linalool (1.4%)	Hydrodistillation	GC-MS/GC-FID/comparison the spectra with WILEY	Antibacterial	[51]	
<i>Litsea cubeba</i> (fruits)	(47) Sabinene (40.2%) (07) $\beta$ -Phellandrene (9.2%) (30) 1,8-Cineol (9.0%)	Steam distillation	GC-MS/comparison the spectra with NIST	Repellent	[52]	
<i>Litsea cubeba</i> (fruits)	(60) Limonol (44.2%) (04) $\beta$ -Linalool (8.8%) (30) 1,8-Cineole (5.4%)	Steam distillation	GC-MS/identified by reference standards	Antifungal	[53]	
					cont.	



▶ Table 1 Continued

Plant species (part used)	Major compounds	Extraction method	Separation/identification method	Bioactivity	Reference
<i>Litsea cubeba</i> (leaf)	(04) Linalool (94.9%) (59) D-limonene (1.52%) (02) Isocaryophyllene (1.27%)	Hydrodistillation	GC-MS/identified by reference standards	Antibacterial Increase in carps immunity	[54]
<i>Nectandra cuspidata</i> (leaf)	(02) $\beta$ -Caryophyllene (26.9%) (61) Bicyclogermacrene (16.0%) (38) Spathulenol (5.2%)	Hydrodistillation	GC-MS/comparison of relative retention index to literature	<i>In vitro</i> cytotoxic Antibacterial	[55]
<i>Nectandra membranacea</i> <sup>b</sup>	(35) $\alpha$ -Pinene (22.4%) (41) $\beta$ -Pinene (12.6%) <sup>g</sup>	Hydrodistillation	GC-MS/comparison the spectra with NIST	Cytotoxic Toxic against brine shrimp	[30]
<i>Nectandra puberula</i> (leaf)	(62) Apiole (22.2%) (02) $\beta$ -Caryophyllene (15.1%) (41) $\beta$ -Pinene (13.3%)	Hydrodistillation	GC-MS/comparison of relative retention index to literature	Cytotoxic <i>in vitro</i> Antibacterial	[55]
<i>Neolitsea kedahense</i> (stem)	(12) $\delta$ -Cadinene (17.4%) (63) 1- <i>epi</i> -Cubebol (11.8%) (64) Cyperotundone (9.0%)	Hydrodistillation	GC-FID GC-MS/comparison of relative retention index to literature	$\alpha$ -Glucosidase inhibitor Antibacterial	[56]
<i>Neolitsea kedahense</i> (leaf)	(02) $\beta$ -Caryophyllene (18.9%) (61) Bicyclogermacrene (18.6%) (65) <i>trans</i> -Muurola-4(14),5-diene (9.8%)	Hydrodistillation	GC-FID GC-MS/comparison of relative retention index to literature	$\alpha$ -Glucosidase inhibitor	[56]
<i>Ocotea bicolor</i> (leaf)	(12) $\delta$ -Cadinene (7.39%) (66) $\beta$ -Sesquiphellandrene (6.67%) (67) $\beta$ -Elemene (5.41%)	Hydrodistillation	GC-MS/comparison of relative retention index to literature	Antioxidant Toxicity against brine shrimp Antibacterial	[57]
<i>Ocotea caniculata</i> (leaf)	(68) $\beta$ -Selinene (20.3%) (02) $\beta$ -Caryophyllene (18.9%) (69) 7- <i>epi</i> - $\alpha$ -Selinene (14.3%)	Hydrodistillation	GC-MS/comparison of relative retention index to literature	Antibacterial Cytotoxic <i>in vitro</i>	[58]
<i>Ocotea caniculata</i> (branch)	(03) Selin-11-en-4- $\alpha$ -ol (20.6%) (68) $\beta$ -Selinene (12.1%) (69) 7- <i>epi</i> - $\alpha$ -Selinene (9.0%)	Hydrodistillation	GC-MS/comparison of relative retention index to literature	Antibacterial Cytotoxic <i>in vitro</i>	[58]
<i>Ocotea caudata</i> (leaf)	(19) Germacrene D (55.8%) (61) Bicyclogermacrene (8.0%) (02) <i>cis</i> - $\beta$ -Caryophyllene (4.6%)	Steam distillation	GC-MS/comparison of relative retention index to literature and WILEY/NIST data library	Antimicrobial	[59]
<i>Ocotea caudata</i> (leaf)	(61) Bicyclogermacrene (29.6%) (19) Germacrene D (19.9%) (35) $\alpha$ -pinene (9.8%)	Hydrodistillation	GC-MS/comparison of relative retention index to literature	Antibacterial Cytotoxic <i>in vitro</i>	[58]
<i>Ocotea caudata</i> (branch)	(12) $\delta$ -Cadinene (13.8%) (19) Germacrene D (8.9%) (70) $\alpha$ -Muurolol (7.8%)	Hydrodistillation	GC-MS/comparison of relative retention index to literature	Antibacterial Cytotoxic <i>in vitro</i>	[58]
					cont.

► **Table 1** Continued

Plant species (part used)	Major compounds	Extraction method	Separation/identification method	Bioactivity	Reference
<i>Ocotea cujumary</i> (leaf)	(02) $\beta$ -Caryophyllene (22.2%) (15) Caryophyllene oxide (12.4%) (71) 2-Tridecanone (7.3%)	Hydrodistillation	GC-MS/comparison of relative retention index to literature	Antibacterial Cytotoxic <i>in vitro</i>	[58]
<i>Ocotea cujumary</i> (branch)	(71) 2-Tridecanone (30.3%) (59) Limonene (20.5%) (02) $\beta$ -Caryophyllene (8.1%)	Hydrodistillation	GC-MS/comparison of relative retention index to literature	Antibacterial Cytotoxic <i>in vitro</i>	[58]
<i>Ocotea duckey</i> (fruit)	(59) dl-Limonene (30.12%) (35) $\alpha$ -Pinene (12.25%) (41) $\beta$ -Pinene (9.89%)	Hydrodistillation	GC-MS/comparison of relative retention index to literature and WILEY data library	Hypotensive and bradycardiac effects	[60]
<i>Ocotea duckey</i> (leaf)	(02) $\beta$ -Caryophyllene (60.54%) (52) $\alpha$ -Humulene (4.63%) (72) $\delta$ -Selinene (4.40%)	Hydrodistillation	GC-MS/comparison of relative retention index to literature and WILEY data library	Hypotensive and bradycardiac effects	[60]
<i>Ocotea duckey</i> (stem)	(14) $\beta$ -Eudesmol (27.51%) (35) $\alpha$ -Pinene (9.02%) (59) dl-Limonene (6.65%)	Hydrodistillation	GC-MS/comparison of relative retention index to literature and WILEY data library	Hypotensive and bradycardiac effects	[60]
<i>Ocotea duckey</i> (roots)	(73) Elemol (24.31%) (67) $\beta$ -Elemene (16.69%) (14) $\beta$ -Eudesmol (13.44%)	Hydrodistillation	GC-MS/comparison of relative retention index to literature and WILEY data library	Hypotensive and bradycardiac effects	[60]
<i>Ocotea quixos</i> (fruit calices)	(23) <i>trans</i> -Cinnamaldehyde (27.9%) (74) Methylcinnamate (21.7%) (30) 1,8-Cineole (8.0%)	Steam distillation	GC GC-MS/comparison of relative retention index to literature	Antioxidant Antibacterial Antifungal	[61]
<i>Ocotea comoriensis</i> <sup>b</sup>	(75) Camphene (18.1%) (76) Borneyl acetate (13.8%) (35) $\alpha$ -Pinene (13.7%)	Hydrodistillation	GC-MS/comparison of relative retention index to literature	Antimalarial	[62]
<i>Ocotea floribunda</i> <sup>b</sup>	(77) Kaurene (34.0%) (35) $\alpha$ -Pinene (22.5%) (41) $\beta$ -Pinene (21.3%) <sup>b</sup>	Hydrodistillation	GC-MS/comparison the spectra with NIST	Cytotoxic Toxic against brine shrimp	[30]
<i>Persea lingue</i> (leaf)	(18) Safole (48.5%) (78) Pentatriacontene (20.42%) (30) Eucalyptol (13.25%)	Steam distillation	GC-MS/comparison of relative retention index to literature and NIST data library	Antibacterial Antifungal	[41]
<i>Rhodostemonodaphne parvifolia</i> (leaf)	(02) $\beta$ -caryophyllene (41.30%) (68) $\beta$ -selinene (13.60%) (10) B-Germacrene (7.75%)	Hydrodistillation	GC-FID GC-MS/comparison of relative retention index to literature and WILEY data library	Antioxidant Acetylcholinesterase inhibitor	[63]
					<i>cont.</i>

▶ Table 1 Continued

Plant species (part used)	Major compounds	Extraction method	Separation/identification method	Bioactivity	Reference
<i>Rhodostemonodaphne parvifolia</i> (bark)	(02) $\beta$ -Caryophyllene (16.20%) (79) <i>epi</i> -Cedrol (13.3%) (04) Linalool (15.4%)	Hydrodistillation	GC-FID GC-MS/comparison of relative retention index to literature and WILEY data library	Antioxidant	[63]
<i>Sassafras albidum</i> <sup>b</sup>	(18) Saffrole (82.04%) (05) Methyl Eugenol (3.03%) (80) $\alpha$ -Calacorene (1.14%)	Commercial sample	GC GC-MS/comparison of relative retention index to literature or WILEY data system library	Antifungal	[15]
<i>Umbellularia californica</i> <sup>b</sup>	(81) Umbellulone (36.7%) (30) 1,8-Cineole (19.5%) (05) Methyl Eugenol (8.4%)	Hydrodistillation	GC-MS/comparison of relative retention index to literature or WILEY data system library	Repellent Larvicide	[64]

<sup>a</sup> Plant collected in two different places, seasons, or from two different individuals. <sup>b</sup> Part used not mentioned. <sup>c</sup> Percentage not described. <sup>d</sup> Method not mentioned. <sup>e</sup> Composition described in [114]. <sup>f</sup> Information described in [115]. <sup>g</sup> Composition described in [116]. <sup>h</sup> Composition described in [117]. <sup>i</sup> FID: flame ionization detector.

substance  $\delta$ -cadinene, its reported activities include antitumoral [79], antimicrobial [80], and acaricide [81]. Sesquiterpene  $\delta$ -cadinene has a cadinan skeleton originating from the cyclization of nerolidine pyrophosphate, which has farnesyl pyrophosphate as a precursor [82], and  $\alpha$ -pinene is a bicyclic monoterpene with many documented activities due to its anti-inflammatory [83, 84] and antiulcerogenic [85] properties.

It is important to note that there is a close relationship between the chirality of organic compounds and their biological activity. The activity is not identical in both enantiomers of an optically active substance. Linalool, for example, is a racemic mixture of two enantiomers, (3*S*)-(+)-linalool (coryandrol) and (3*R*)-(-)-linalool (licareol), both of which have distinct properties [86, 87]. The anesthetic property of (3*S*)-(+)- and (3*R*)-(-)-linalool has been tested on silver catfish (*Rhamdia quelen*), showing that (3*R*)-(-)-linalool demonstrated clear advantages at a lower concentration [88]. Regarding anticonvulsant activity, de Sousa et al. [89] demonstrated that (3*R*)-(-)-linalool and the racemate form were more active than the (3*S*)-(+)- enantiomer, which had effects compatible with known anticonvulsant agents (diazepam, phenytoin). In a review presented by Aprotosoae et al. [86], it was shown that although (3*S*)-(+)- and (3*R*)-(-)-linalool have similar activity profiles, the effects of (3*R*)-(-)-linalool is more intense.

### Antioxidant activity

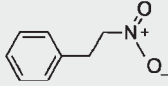
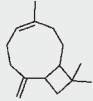
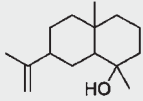
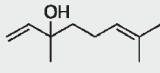
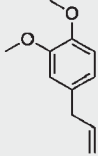
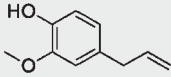
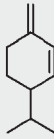
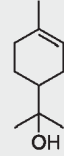
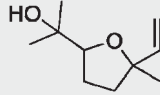
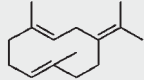
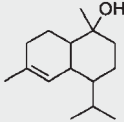
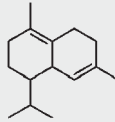
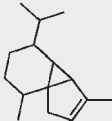
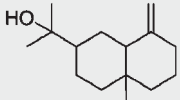
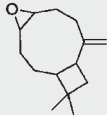
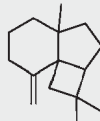
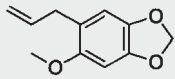
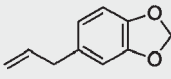
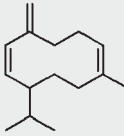
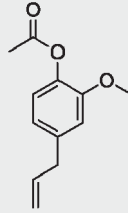
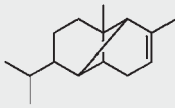
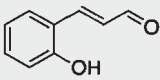
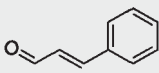
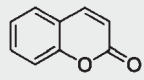
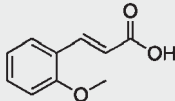
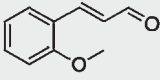
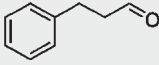
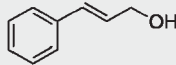
The human organism is subjected to oxidative stress caused by oxygen reactive (ORS) and nitrogen reactive species. These species might be endogenous, generated through the cell's own metabolism and aerobic processes, or exogenous, from the environment [90–92]. Thus, an excess of ORS in the organism triggers deleterious effects on the cell membrane, proteins, carbohydrates, DNA, and RNA. Reactive species are also related to degenerative diseases such as cancer, cardiopathies, and atherosclerosis [93, 94].

In normal physiological conditions, ORS production is balanced by an efficient antioxidant system, formed by molecules capable of removing the reactive species and preventing cell damage [95]. According to Halliwell [92], antioxidants comprise substances that, in low concentrations, significantly delay or inhibit the oxidation of the substrate. Antioxidant compounds from fruits, vegetables, and herbs have been extensively studied, among which, vitamins ( $\alpha$ -tocopherol,  $\beta$ -carotene, and ascorbic acid), carotenoids, flavonoids, other polyphenols, furanoids, thiols, and EOs stand out [96]. The antioxidant properties of EOs have been studied in a number of *in vitro* assays, with such activity being conferred mainly by the presence of terpenoids and phenolic compounds [11].

Studies performed with EO extracted from *Rhodostemonodaphne parvifolia* Madriñán showed its free radical scavenging activity in chromatography plates. However, a quantitative assay [antioxidant activity against 2,2-diphenyl-1-picrylhydrazyl (DPPH)] demonstrated activity only above 1000 mg/mL [63].

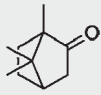
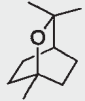
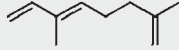
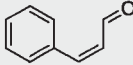
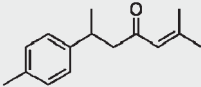
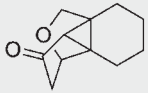

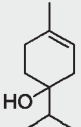
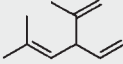
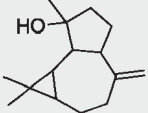
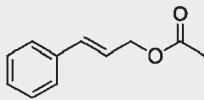
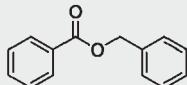

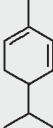
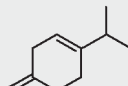
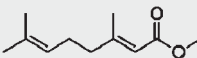
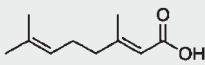
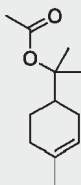


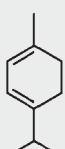

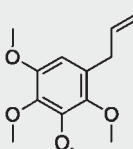
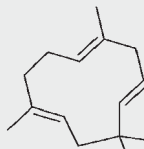
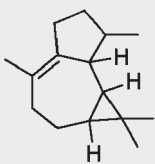
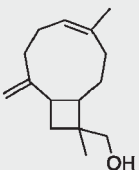
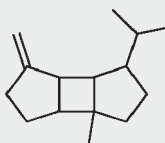
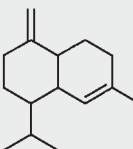
Bruni and collaborators [61] demonstrated that the EO from fruit calyces of *Ocotea quixos* (Lam.) Kosterm reduced 52% of the DPPH radical. On the other hand, results from the inhibition of linoleic acid oxidation through the  $\beta$ -carotene/linoleic acid assay were not expressive. This reveals different EO behavior in free

► **Table 2** Structures of the major chemical constituents from the listed Lauraceae species in the studies selected through this systematic review.

			
(01) 1-Nitro-2-phenylethane	(02) $\beta$ -Caryophyllene	(03) Selin-11-en-4- $\alpha$ -ol	(04) Linalool
			
(05) Methyleugenol	(06) Eugenol	(07) $\beta$ -phellandrene	(08) $\alpha$ -Terpineol
			
(09) <i>trans</i> -Linalool oxide	(10) Germacrene B	(11) $\alpha$ -Cadinol	(12) $\delta$ -Cadinene
			
(13) $\alpha$ -Cubebene	(14) $\beta$ -Eudesmol	(15) Caryophyllene oxide	(16) $\beta$ -Panasinsene
			
(17) Sarisan	(18) Safrole	(19) Germacrene D	(20) Eugenol acetate
			
(21) $\alpha$ -Ylangene	(22) 2-Hydroxy-cinnamaldehyde	(23) Cinnamaldehyde	(24) Coumarin
			
(25) <i>cis</i> -2-Methoxycinnamic acid	(26) 2-Methoxy-cinnamaldehyde	(27) Hydrocinnamaldehyde	(28) Cinnamyl alcohol

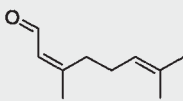
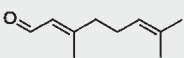
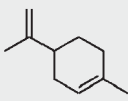
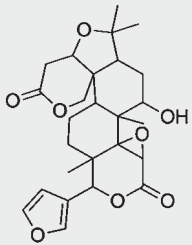
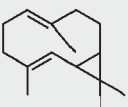
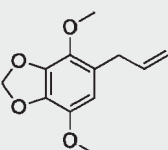
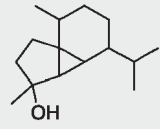
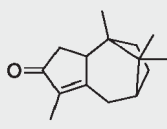
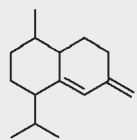
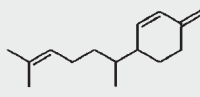
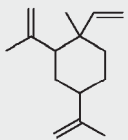
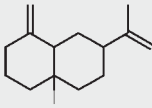
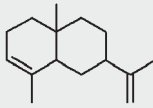
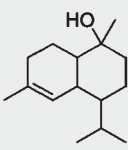
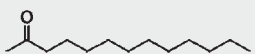
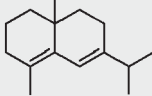
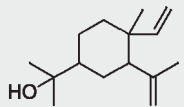
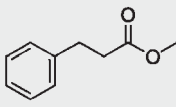

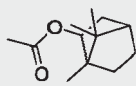
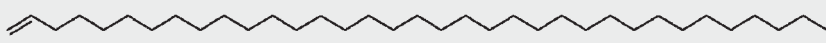
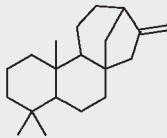
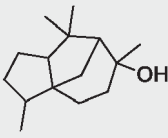
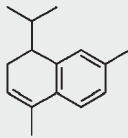
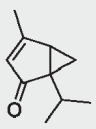
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► Table 2 Continued

			
(29) Camphor	(30) 1,8-Cineole	(31) 3,7-Dimethyl-1,3,7-octatriene	(32) <i>cis</i> -Cinnamaldehyde
			
(33) Aromatic tumerone	(34) 11-Oxatetracyclo[5.3.2.0(2,7).0(2,8)]dodecan-9-one	(35) $\alpha$ -Pinene	(36) Terpinen-4-ol
			
(37) Santolina triene	(38) Spathulenol	(39) Cinnamyl-acetate	(40) Ascabin
			
(41) $\beta$ -Pinene	(42) $\alpha$ -Phellandrene	(43) $\beta$ -Terpinene	(44) Methyl geranate
			
(45) Geranic acid	(46) $\alpha$ -Terpinyl-acetate	(47) Sabinene	(48) $\beta$ -Ocimene
			
(49) $\alpha$ -Terpinene	(50) <i>trans</i> -Sabinene hydrate	(51) 6-Methoxy-elemicin	(52) $\alpha$ -Humulene
			
(53) Viridiflorene	(54) 14-Hydroxy-9-epi-B-caryophyllene	(55) $\beta$ -Bourbonene	(56) $\gamma$ -Cadinene

continued

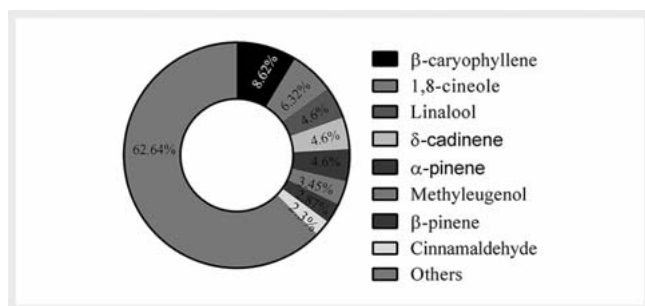
► Table 2 Continued

			
(57) Z-Citral	(58) E-Citral	(59) Limonene	
			(60) Limonol
(61) Bicylogermacrene	(62) Apiole	(63) 1-epi-Cubebol	
			
(64) Cyperotundone	(65) <i>trans</i> -Muurolo-4(14),5-diene	(66) $\beta$ -Sesquiphellandrene	(67) $\beta$ -Elementene
			
(68) $\beta$ -Selinene	(69) 7- <i>epi</i> - $\alpha$ -Selinene	(70) $\alpha$ -Muurolol	(71) 2-Tridecanone
			
(72) $\delta$ -Selinene	(73) Elemol	(74) Methyl cinnamate	(75) Camphene
			
(76) Bornylacetate	(78) Pentatriacontene		
			
(77) Kaurene	(79) <i>epi</i> -Cedrol	(80) $\alpha$ -Calacorene	(81) Umbellulone

radical reduction and in the inhibition of oxidation, suggesting that polar components from EOs might be responsible for the activities in the DPPH assay.

Studies performed using the *Beilschmiedia* genus revealed antioxidant activity in *Beilschmiedia madang* Blume, *Beilschmiedia kunstleri*, *Beilschmiedia maingayi*, *Beilschmiedia penangiana*, and

*Beilschmiedia pulverulenta* [16,17]. From the evaluated species, *B. maingayi* showed the best results with an  $IC_{50\%}$  of  $84.7 \mu\text{g} \cdot \text{mL}^{-1}$  and  $108.3 \mu\text{g} \cdot \text{mL}^{-1}$  in the DPPH and ABTS assays, respectively. The species also exhibited 125.9% inhibition in the  $\beta$ -carotene/linoleic acid assay and total phenolic content of  $288.2 \text{ mg GA} \cdot \text{g}^{-1}$  [16,17].



► Fig. 2 Chemical constituents most found in the listed Lauraceae species.

## Antibacterial activity

Medicinal plants are a viable therapeutic option to use against microorganisms that are resistant to antibiotics. The products of the secondary metabolisms of plants can operate in two ways. The first consists of boosting the antibacterial activity, favoring the activity of antibiotics with limited action due to bacterial resistance and, consequently, minimizing toxicity. The second involves the improvement of the response of the immune system to infection, thus the products can act as virulence extenuating agents [97,98].

Among the mechanisms by which EOs present antibacterial activity, one may cite their interference in the phospholipid double layer from the bacterial cell wall, an increase in the permeability and loss of cell constituents, and the alteration of the enzymatic systems involved in energy and the production of structural components or destruction of genetic material [99]. Bacteriostatic and/or bactericidal activities of EOs are exerted mainly by oxygenated terpene compounds (e.g., alcohols and phenolic terpenes), however, some hydrocarbons also have antibacterial effects [100,101].

Researches using *Beilschmiedia* genus demonstrated antibacterial activity of EO extracted from the leaves and barks of *B. madang* Blume, *B. kunstleri*, *B. maingayi*, *B. penangiana* [16], and *B. pulverulenta* [19]. EO from *Laurus nobilis* has also been reported as a good antibacterial agent [43–46].

## Antifungal activity

The treatment of diseases caused by fungi is limited due to the difficulties inherent in a diagnosis. Available antifungal drugs have expressive toxicity and can cause both resistance and infection recurrence. Thus, the search for antifungals originating from plants might enable the development of innovative medicines [102,103]. EOs present some degree of antifungal activity and may act as fungistatic and/or fungicide agents, depending on their concentration [104]. This activity has been attributed to a range of substances, including phenolic compounds, monoterpenes, and terpenoids [105]. Considering the number of chemically distinct compounds in EOs, it is highly probable that the antifungal activity involves different mechanisms of action, which are, in part, linked to hydrophobicity [99,100].

These mechanisms are not yet well elucidated; nonetheless, studies indicate that most EOs are capable of interacting with lip-

idic structures and causing modifications to the cell wall of the pathogen, leading to increased permeability of the cytoplasmic membrane and damaging the processes essential to cell survival [106]. The inactivation of certain enzymes, including those involved in energy production and the synthesis of structural components, is one possible such mechanism [107].

The antifungal activity of EO extracted from *Cinnamomum* species is extensively reported in the literature. An essential oil from *Cinnamomum cassia* inhibited strains of *Aspergillus flavus* and *Aspergillus oryzae* at 125 ppm and 250 ppm, respectively [22], four species of *Candida* (*Candida albicans*, *Candida tropicalis*, *Candida glabrata*, and *Candida Krusei*), and filamentous and dermatophyte fungi [24]. *Cinnamomum zeylanicum* showed activity against *Phomopsis helianthi*, *Cladosporium fulvium* and *Cladosporium clado-sporioide* [15]. Of the tested fungal species, *Trichoderma viride* presented the greatest resistance to the oil [15].

## Anti-inflammatory activity

The inflammatory reaction is a physiopathological response of the host against aggressive stimuli, e.g., pathogenic and irritant agents or damaged cells. The reaction is classified as acute or chronic, and involves a cascade of biochemical events [108,109]. In inflammatory responses, there is an increase in permeability of the endothelial coating and thus a higher influx of leukocytes from the blood stream to the interstice. Intense oxidative processes and the release of cytokines (interleukins and TNF- $\alpha$ ) also occur. At the same time, there is an induction of activity in many enzymes (oxygenases, nitric oxide synthase, peroxidases), together with the arachidonic acid metabolism. The expression of adhesion molecules, such as intercellular adhesion molecules (ICAM) and vascular cell adhesion molecules, also participates in this process [110]. The anti-inflammatory activity of EOs may be related to its antioxidant activity, and to its interaction in signaling cascades involving cytokines, the regulation of transcription factors, and the expression of proinflammatory genes [111].

In addition to other activities, the *Beilschmiedia* genus demonstrated anti-inflammatory potential for *B. kunstleri*, *B. maingayi*, and *B. penangiana* through the lipoxygenase (LOX) assay. From these species, EO from the leaves and bark of *B. maingayi* exhibited the best results, with inhibitions of 77.0 and 73.5%, respectively. This activity was attributed to the presence of  $\beta$ -caryophyllene, limonene, and caryophyllene oxide, which are known to be LOX inhibitors [16].

Another study using the EO extracted from the leaves of *Cinnamomum osmophloeum* (60  $\mu$ g/mL) in mice showed a high capability for inhibiting the expression of proIL-1 $\beta$  in macrophages activated by lipopolysaccharides (LPS). Furthermore, at 60  $\mu$ g/mL, the EO was efficient at inhibiting IL-1  $\beta$  and IL-6 but not TNF- $\alpha$ , suggesting that the EO presented *in vitro* activity [28].

## Toxic activity

Among the preliminary evaluations for the toxicity of EOs and extracts derived from plants is the assay against *Artemia salina* [112]. EO from the bark of *Aniba canelilla* was evaluated by Da Silva et al. [13], who compared the activity of the EO with one of its isolated major compounds (1-nitro-2-phenylethane). From the assays performed, toxic activity was observed in both samples, with a low

IC<sub>50</sub>s of 21.61 µg/mL for the EO and 20.37 µg/mL for 1-nitro-2-phenylethane. Silva and collaborators [14] undertook a complementary evaluation of the toxicity of EO from the leaves of *A. canelilla* according to the same method, however, the IC<sub>50</sub> obtained here was 68.37 µg/mL, approximately three times higher than the EO of the bark. It is important to note that, although 1-nitro-2-phenylethane was found as a major compound and with similar percentages in both EOs, the biological activity of samples obtained from natural products occurs through synergism between all substances present. Nevertheless, both samples can be considered very toxic [112].

EOs from four other Lauraceae species were also evaluated: *Licaria canella* [14], *Cinnamomum tonduzii*, *Nectandra membranacea*, and *Ocotea floribunda* [30]. All samples presented an IC<sub>50</sub> lower than 40 µg/mL. The EOs of leaves of *N. membranacea* and *O. floribunda* presented a lethal concentration 50% below 5 µg/mL (IC<sub>50</sub> = 3.7 µg/mL for both) [30].

The toxicity of the EO from *O. floribunda* was also tested in cell lines through the tetrazolium reduction method (MTT). This assay evaluates cell viability [113], and the sample analyzed caused the death of around 78% of human hepatocarcinoma cells (Hep G2) at 100 mg/mL [30]. On the other hand, the EO of leaves and stems from *Endlicheria citriodora*, when evaluated through the Alamar Blue assay in three cell lines (murine fibroblast and melanoma, and gastric adenocarcinoma) showed low toxicity, since at 50 µg/mL, the samples did not cause the death of 50% of the cells [42].

The toxic potential or absence of toxicity determines the uses and applications of the EOs. An example of this situation is the EO from the leaves of *A. canelilla* and *L. canella*. The samples presented moderate activity against *Leishmania amazonensis*; later on, both EOs were studied with regard to the toxicity in noninfected macrophages [14]. For both samples, low toxicity was observed [14]. This is considered promising, since it implies that the EO has the potential to treat leishmaniasis without causing problems to the patient.

## Conclusion

The present review concludes that the Lauraceae family includes several species that produce essential oils, with chemical compositions predominated by sesquiterpene  $\beta$ -caryophyllene and monoterpene 1,8 cineol. Both of these compounds have several biological and pharmacological potentials, which have been proven in previous literature.

Among the activities of the essential oils of the species presented in the reviewed studies, we highlight (i) the antioxidant property evidenced by means of different chromatography techniques, (ii) their antimicrobial activity, wherein several strains of microorganisms were inhibited, (iii) their anti-inflammatory potential, and (iv) their toxic activity. Thus, according to the chemical composition and activity of the essential oils, their use can be directed towards the cosmetic, food, or pharmaceutical industry for diverse applications.

## Acknowledgements

The authors extend their appreciation to the PhD Program in Pharmaceutical Sciences of the Federal University of Parana, Brazil.

## Conflict of Interest

The authors declare no conflict of interest.

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