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Laurel, *Laurus nobilis* L.: a review of its botany, traditional uses, phytochemistry and pharmacology

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Abstract *Laurus nobilis* L. (Lauraceae), commonly known as laurel, is an evergreen and edible tree that possess biological properties positively correlated with human health. It is a very popular plant known since ancient times in traditional medicine and considered a symbol of peace and sign of victory in military and sport competitions. Laurel is used as flavoring agent in kitchen for meat, fish, broths, and vegetables. The plant shows a rich content of metabolites including proteins, free sugars, organic acids, PUFA and tocopherols and exhibit a biological potential with a wide range of bioactivity including antimicrobial and antioxidant properties. This review is aimed to contribute to the knowledge of the plant by providing a critical overview of the botanic characteristics, the traditional uses, the plant chemistry and the biological activities.

Keywords Laurel · Bay tree · Sweetbay · Food plant · Wild plants · Chemical compounds · Bioactive metabolites

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Introduction

Laurus nobilis L., known as laurel (Lauraceae family) is a native plant of the Mediterranean basin and widely diffused in Northern Africa, Western Asia and Southern Europe (Parthasarathy et al. 2008). It is one of the best-known plants in the ancient Greece and Roman times where it was considered as a symbol of peace and sign of victory both in military and sport competitions. At that time, the branches were crossed to create crowns to be placed on the heads of the game winners indicating recognition and esteem and therefore the greatest honor. The poets who won and received the bay laurel wreath became "graduate poets" and people worthy of the most immense and royal esteem for this reason became "nobilis" (Parthasarathy et al. 2008). Even today we use this term when obtaining a degree and put the bay leaf crowns of the heads of the laureates.

Several myths and legends are reported on bay laurel based on its consideration as a sign of prosperity and well-being. In the language of flowers and plants, laurel is considered the symbol of power, victory and glory and being an evergreen plant, it is also a symbol of immortality (De Cleene and Lejeune 2003).

Laurel is used in the kitchen as a spicy fragrance and flavour to meat, fish, broths, and vegetables. It is a component of a typical Italian plant infusion used as digestive, named "canarino".

The leaves are traditionally used to reduce high blood sugars, fungal and bacterial infections, and to cure gastrointestinal pains, eructation and flatulence. The Roman naturalist Pliny the Elder indicated the following series of ailments treated with bay laurel oil: paralysis, spasms, sciatica, bruises, headaches, catarrhs, ear infections, and rheumatism (Caputo et al. 2017; Chahal et al. 2017).

The plant exhibits several bioactivities including anticonvulsive, antiepileptic, anti-inflammatory, and antioxidant properties (Caputo et al. 2017; Chahal et al. 2017). This last activity was mainly studied and associated to the high content in the plant leaves of flavonoids and phenolics. In particular, apigenin, luteolin, kaempferol, myricetin and quercetin were the major flavonoid derivatives along with the related flavan-3-ols. In addition, the plant shows a rich content of free sugars, proteins, organic acids, PUFA and tocopherols (Dias et al. 2014).

This review aimed to contribute to the knowledge of laurel, *L. nobilis,* by providing an overview of its botany, traditional uses, phytochemistry and pharmacology.

Botanical description

L. nobilis L. is a multibranched, aromatic, broadleaf, slender, evergreen tree, or large shrub belonging to the Lauraceae family. Commonly called laurel, bay tree, Grecian laurel, bay leaf or sweetbay, it is native to the Northern Africa, Western Asia and southern Europe (Parthasarathy et al. 2008). In natural conditions it reaches up to 10 m, with thin branches forming a dense pyramidal crown. Bark is smooth, thin and pale gray. Laurel is a dioecious tree, with male and female flowers on separate plants. Leaves are alternate, short petioled, up to 10 long, lanceolate, or oblong-lanceolate, acute, coriaceous, pellucid-punctate, and with revolute, entire margins. The upper surface is glabrous and shiny glossy dark green; the lower surface is hairless, dull olive to brown with a prominent midrib and veins. Both male and female flowers are bright yellow-green, beared on short, 4–5 flowered, racemes appearing in early to mid-spring. Male flowers with 8–14 stamens 4–5 mm long, most of them with 2 basal glands. The female flowers are about 4–5 mm long, with 2–4 staminodes and contain nectaries; the ovary is superior, scarcely sunk in the receptacle, style short. Fruit is one-seeded, 1–1.5 long, ovoid, berry, with a shiny dark purple, thin pericarp, which, when broken, discloses a kernel whose seed coat adheres to the inner surface of the pericarp. The male plants produce more flowers per branch than the female plants and the mean life of male flowers is shorter than that of female (Pacini et al. 2014). The pollination is entomophilous, with honeybees as main pollinators (Brickell 2008).

Traditional uses

Laurel is traditionally used as an herb (called bay leaf) to season roast meats, stews, snails, fish, sauces, soups, and boiled chestnuts, (Kermath and Bennett 2014; Alarcón et al. 2015; Motti et al. 2020). Laurel is also widely reported as a traditional herbal drug (Table 1) in many countries all around the world like Algeria, Brazil, Cyprus, Greece, Italy, Serbia, and Turkey. Leaves and fruits are used orally or topically to treat a wide range of diseases (Fig. 1). Based on the classifications of diseases and remedies in ethnomedicine and ethnopharmacology suggested by Staub et al. (2015), the major uses of *L. nobilis* include treatments for gastro-intestinal complaints including indigestion, constipation, flatulence also as carminative, diarrhea, hemorrhoids, and stomach aches. This species is also reported to treat kidney diseases, and for the treatment of cough, colds, influenza, and sore throat. Laurel leaves are one of the main ingredients of a preparation used for the treatment of respiratory ailments called in many cases 'Ricotto' or 'Ricuotto', still in use today and found in the traditional phytotherapy of central and southern Italian regions (Barone 1963; Scherrer et al. 2005; Motti et al. 2009; Idolo et al. 2010).

L. nobilis is reported as mild sedative and against headache but also used as analgesic, antirheumatic and diaphoretic. In the gynecological field it is reported for the dysmenorrhea treatment, as galactagogue and abortifacient. Furthermore, laurel decoction is used for cardio-vascular diseases and to treat lower blood pressure. In Turkey, branches chopped up, peeled, and put into water are used against scorpion or snake bites and bee bites (Honda et al. 1996; Tuzlacı and Tolon 2000).

The essential oil was used in folk medicine to treat rheumatisms and dermatitis. However, attention needs to be given to the dosage because it can cause allergic effects (Kilik et al. 2004). Berries show ahigh fatty

acids content, and thus it is used for soap production in cosmetics to treat acme and dandruff (Kilik et al. 2004).

Based on the 77 studies providing adequate and relevant data leaves (80.8%) are the most frequently used plant parts. According to the reported data, decoction (65.2%) is the most frequent preparation methods used (Fig. 2).

The essential oils or leaf fumigation of laurel are also used as insect repellents and insecticides against home insects and crop pests (Baydoun et al. 2017).

Phytochemical analysis

Essential oils

Tables 2 and 3 summarize the main metabolites extracted from the different parts of the plant, their quantity, and the methods used for their analysis.

Most of the studies have focused on the analysis of essential oils extracted from laurel leaves (Table 2). The main extraction method used to separate the essential oils from leaves was hydrodistillation of powdered dried leaves for few hours, with a very variable final yield. However, other techniques can be used with similar results and here we provide a brief overview. Nafis et al. (2020) performed hydrodistillation for 4 h, obtaining 2.5% (v/w) based on dry weight. Similarly, Stefanova et al. (2020) isolated oils by 3 h-long hydrodistillation from two different varieties and obtained 1.42 ± 0.01% (v/w) yield for Greek variety, and 4.54 ± 0.04% (v/w) yield for Georgian variety. Moreover, Jemâa et al. (2012) performed hydrodistillation for 4 h on three different leaves varieties, obtaining a yield of 0.584, 0.46 and 0.655%. Ivanović et al. (2010) carried out an experiment to compare two different methods of extraction for essential oils: a 4 h-hydrodistillation, which resulted in a yield of 1.43%, and 1.4 h-long supercritical CO_2 extraction, obtaining 1.37% of extract yield. Although the two yields were comparable, the compositions of the two extracts were significantly different. For example, 1,8-Cineole, the main component of the hydrodistillated fraction, was 13 times more abundant in hydrodistillated extract than in supercritical CO_2 extract. Another interesting technique, solvent-free microwave extraction (SFME), was used by Bendjersi et al. (2016) and compared to hydrodistillation. The final products were different in turbidity, since SFME produced a clearer extract than the hydrodistillated one, even though the final essential oil yields of the two processes were comparable (0.61% for SFME vs 0.86% for hydrodistillation). Finally, Conforti et al. (2006) compared a wild and a cultivated varieties of *L. nobilis*.. They performed extraction of essential oils using n-hexane and they obtained totally different yields from them. Wild laurel yielded 0.11% of non-polar fraction, while cultivated laurel contained 1.12% of it. Probably, these large differences between the mentioned works were due to environmental and genotypic factors.

The GC–MS analysis of the essential oils of Laurel resulted in hundreds of different components, but only few dozens of molecules were repetitively found in several works. The most frequent molecules belong to the class of terpenes, unsaturated hydrocarbons mainly produced by plants. They have many biological functions, from being precursors of steroids to plant defense and pollinator attractors thanks to their pleasant and powerful odors. The main terpenes found in essential oils are monoterpenes and their derivatives, monoterpenoids, both classes formed by two isoprene units (10 carbons) with several functional groups attached to them. They were also the most abundant, and include 1,8-Cineole (or Eucalyptol), Camphene, Limonene, *p*-Cymene, Sabinene, Terpinen-4-ol, Linalool, α-Pinene, α-Terpinene, α-Terpineol, α-Thujene. Some of them are regularly found in many plants. Eucalyptol was the most abundant monoterpenoid, present between 25 and 60% in many studies. Moreover, other common monoterpenes were α-Pinene, which ranged between 2.5 and 32%, Sabinene (0.07–13%) and Linalool (0.1–18%) (Table 2).

Moreover, essential oils contain moderate quantities of Eugenol and Methyl eugenol. Eugenol is an allylbenzene, used in perfumes and flavoring that can be found in many plants' essential oils. Because of the hydroxyl group and the methoxy group, Eugenol is able to scavenge free radicals and avoid reactive oxygen species formation, while Methyl eugenol is a phenylpropanoid and its main role is to attract pollinators. Both of them were moderately abundant in laurel leaves (0.1–5.1%/0.9–21.3%).

Interestingly, since these molecules represent a large portion of the essential oils, when leaves get harvested in different seasons. Shokoohinia et al.

Table 1 Traditional uses of *L. nobilis*

Ailment	Preparation	Country	References
Abortifacient	n.m	BR	Di Stasi et al. (2002)
Acne	Essential oil	TU	Gürdal and Kültür (2013)
Antidiaphoretic	Decoction	IT	Ballero et al. (2001)
Antiemetic	Infusion	IT	Ballero et al. (2001)
Antineuralgic	n.m	IT	Vitalini et al. (2009)
Anti-inflammatory	Infusion, decoction, essential oil	GR-IT	Loi et al. (2005), Foddis and Maxia (2006), Sanna et al. (2006), Licata et al. (2016), Martelli et al. (2016), Axiotis et al. (2018)
Antipiretic	Infusion	IT-TU	Camangi and Tomei (2003), Ugulu et al. (2009)
Antirheumatic	Decoction, infusion	IT	Bruni et al. (1997), Foddis et al. (2006)
Antiseptic	Leaf fumes, decoction,	IT	Leporatti and Corradi (2001), Loi et al. (2004), Sanna et al. (2006), Idolo et al. (2010)
Aperitif	Infusion	IT-TU	Pieroni (2000), Fakir et al. (2009)
Asthmna	Decoction	IT	Loi et al. (2004)
Cardiovascular diseases	Decoction, infusion	AL-IT-TU	Loi et al. (2004), Ouelbani et al. (2016)
Carminative	Decoction	IT-TU	Camangi and Tomei (2003), Guarrera (2003), Everest and Ozturk (2005), Maxia et al. (2008)
Cold	Decoction	IT-SP-TU	Everest and Ozturk (2005), Scherrer et al. (2005), Savo et al. (2011), Gürdal and Kültür (2013), Tuttolomondo et al. (2014a, b), Menale and Muoio (2014), Vitalini et al. (2015), Fortini et al. (2016), Menale et al. (2016), Motti and Motti (2017), Mautone et al. (2019), Mattalia et al. (2020)
Cough	Decoction	IT-SE	Palmese et al. (2001), Maccioni et al. (2008), Tuttolomondo et al. (2014a), Menale and Muoio (2014), Menale et al. (2016, 2021), Motti and Motti (2017), Mattalia et al. (2020)
Diaphoretic	Decoction, infusion	IT-PA-TU	Camangi and Tomei (2003), Everest and Ozturk (2005), Fakir et al. (2009)
Diarrhoea	Decoction	IT	Bruni et al. (1997), Maxia et al. (2008)
Digestive	Decoction, infusion	CY-IT-TU	Atzei et al. (1991), Amico and Sorce (1997), Vázquez et al. (1997), Uncini Manganelli and Tomei (1999), Pieroni (2000), Ballero et al. (2001), Leporatti and Corradi (2001), Pieroni et al. (200(2), Guarrera (2003), Loi et al. (2005), Pieroni and Quave (2005), Scherrer et al. (2005), Everest and Ozturk (2005), Della et al. (2006), Arcidiacono et al. (2007), Passalacqua et al. (2007), Maxia et al. (2008), Ugulu et al. (2009), Cornara et al. (2009), Fakir et al. (2009), Savo et al. (2011), Aleo et al. (2013), Leto et al. (2013), Tuttolomondo et al. (2014a, b), Bellia and Pieroni (2015), Vitalini et al. (2015), Dei Cas et al. (2015), Guarrera et al. (2015), Licata et al. (2016), Menale et al. (2016), Mautone et al. (2019)
Diuretic	Decoction	IT-TU	Everest and Ozturk (2005)
Dysmenorrhea	Decoction	IT	Bianchi et al. (2004), Maxia et al. (2008), Motti and Motti (2017)
Earache	Fried in oil, fomentation	IT	Di Novella et al. (2013), Mattalia et al. (2020)
Galactagogue	Infusion	IT	Guarrera and Lucia (2007)
Hair loss and care	Compress, essential oil, soap	IT-TU	Gürdal and Kültür (2013), Fortini et al. (2016), Sargin and Büyükcengiz (2019)
Headache	Eaten raw, infusion	IT-TU	Amico and Sorce 1997), Ertuğ Füsun (2015), Menale et al. (2016), Mattalia et al. (2020)
Hemorrhoids	Eaten raw, decoction, infusion	IT-TU	Honda et al. 1996), Tuzlacı and Erol 1999), Kazan (2007), Ugurlu and Secmen (2008), Ugulu et al. (2009), Vitalini et al. (2015)

Table 1 continued

Ailment	Preparation	Country	References
Intestinal pain	Infusion, decoction	BR-IT	Bruni et al. 1997), Leporatti and Corradi (2001), Di Stasi et al. (200(2), Guarrera et al. (2005), Passalacqua et al. (2007), Maxia et al. (2008), Cornara et al. (2009), Motti et al. (2009), Idolo et al. (2010), Savo et al. (2011), Menale et al. (2021, 2016), Motti and Motti (2017), Mattalia et al. (2020)
Kidney diseases	Decoction	AL-BR-PA-TU	Ali-Shtayeh et al. (2000), Everest and Ozturk (2005)
Lower blood pressure	Decoction	IT	Idolo et al. (2010), Vitalini et al. (2015)
Pain	Decoction, infusion	SP-TU	Blanco et al. (1999), Tuzlacı and Erol (1999), Ugulu et al. (2009)
Prostatitis	n.m	TU	Kazan (2007)
Rheumatism	Essential oil, decoction, infusion, soap	IT-PA-TU	Yesilada et al. (1993), Vázquez et al. (1997), Ali-Shtayeh et al. (2000), Abay and Kılıç (2001), Everest and Ozturk (2005), Fakir et al. (2009), Ertuğ (2004), Sargin and Büyükcengiz (2019), Menale et al. (2021)
Scorpion bite	Chewed	TU	Honda et al. 1996)
Sedative, stress	Infusion, decoction	IT-TU	Ballero et al. (2001), Leporatti and Corradi (2001), Pieroni et al. (2004), Everest and Ozturk (2005), Pieroni and Quave (2005), Passalacqua et al. (2007), Maccioni et al. (2008), Montesano et al. (2012), Di Sanzo et al. (2013), Menale et al. (2021)
Snake bite	Chopped	TU	Tuzlacı and Tolon (2000)
Sore troath	Decoction	IT	Pieroni et al. (2004), Montesano et al. (2012), Guarrera et al. (2015)
Spasmolitic	Decoction	IT	Leporatti and Corradi (2001), Camangi and Tomei (2003), Di Novella et al. (2013)
Stomachache	Decoction, infusion	IT-TU	Amico and Sorce (1997), Yeşilada et al. 1999), Bianchi et al. (2004), Loi et al. (2004), Everest and Ozturk (2005), Kazan (2007), Napoli (2008), Cornara et al. (2009), Savo et al. (2011), Aleo et al. (2013), Di Sanzo et al. (2013), Gürdal and Kültür (2013), Vitalini et al. (2015), Menale et al. (2016), Motti and Motti (2017)
Stomachic	Decoction	IT	Atzei et al. (1991), Guarrera et al. (2005), Fortini et al. (2016)
To induce vomiting	Decoction	TU	Yeşilada et al. (1999)

n.m. not mentioned

AL Algeria, *BR* Brazil, *CY* Cyprus, *GR* Greece, *IT* Italy, *PA* Palestine, *SE* Serbia, *SP* Spain, *TU* Turkey

(2014) found that 1,8 cineole was the most varied molecule, with a 10% difference between June and December. The second most abundant molecule varied among the seasonal harvest, being δ-3-carene, Camphor, Camphene and Sabinene respectively in March, June, September and December, while eugenol, methyl eugenol and α-terpenyl acetate did not show variation. Furthermore, another work harvested *L. nobilis* leaves from October to July and found an increasing trend for α- and β-Pirene, Sabinene, δ-3-Carene, and a decreasing trend for Borneol, α-Terpinyl acetate and Eugenol (Marzouki et al. 2009).

Elemicin is a phenylpropene that can be found in essential oils from diverse plants. In the considered studies elemicin was present between 0.14 and 4.958% of the essential oils weight. Rossi et al. (2007) found that elemicin exhibited an antimicrobial activity against *Campylobacter jejuni*. Moreover, they disproved the theory supported by previous studies that elemicin possess genotoxic potential. The same thing was stated by De Vincenzi et al. (2004) who examined the literature and found no proves that elemicin have short-term chronic toxicity.

Among higher alkanes, *n*-Heneicosane, *n*-Heptacosane, *n*-Heptadecane, *n*-Hexacosane, *n*-Octacosane, *n*-Pentacosane, *n*-Tetracosane, *n*-Tricosane were consistently found in the essential oils from *L. nobilis* leaves, and their individual quantities never reached

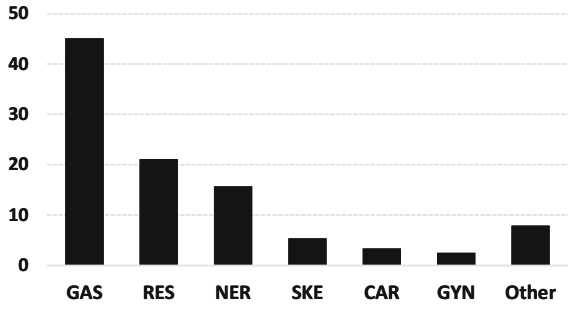

Fig. 1 Percentages of use of laurel for different ailments categories. (Disease's classifications according to Staub et al. (2015): *CAR* Cardiovascular diseases, *GAS* Gastrointestinal problems, *GYN* Gynecology, *NER* Nervous system, *RES* Respiratory complaints, *SKE* Skeleto-muscular system)

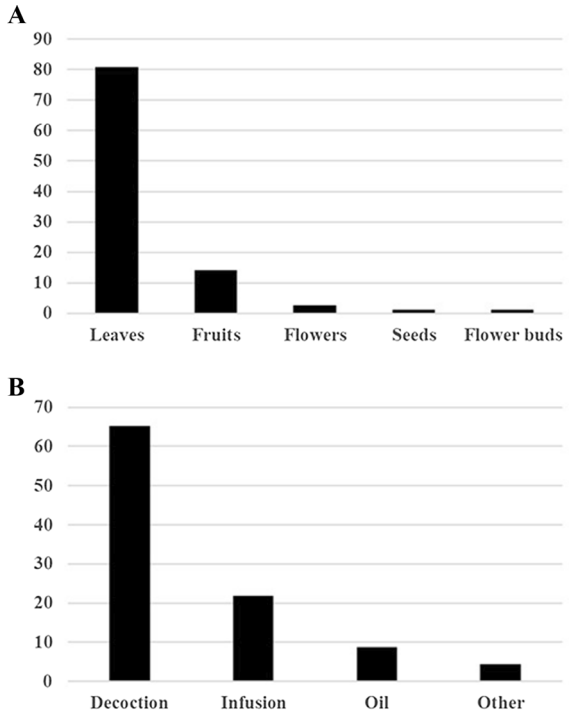

Fig. 2 Plant parts used for medical applications **A** and main modes of preparation **B**, (Percentage values)

1% of the oil mass in the studies we considered (Table 2). The composition of the essential oils at different levels of altitude was studied by Yilmaz and Deniz (2017). Their analysis showed that few compound were found to be significantly increased or decreased dependently on the increase of the altitude. α- and β-Pinene, 1,8-cineole, β-Elemene and Methyl Eugenol showed a decreasing trend in some species, whereas Linalool showed an increasing trend (Yılmaz and Deniz 2017).

Polar components

Less commonly, *L. nobilis* leaves were subjected to the extraction of molecules with different procedures to retain the polar fraction, using mixtures of ethanol, methanol, ethyl acetate and water.

We listed some relevant examples as follows. Yoshikawa et al. (2000) used methanol to extract polar molecules and then ethyl acetate:water to partition them. Hibasami et al. (2003) focused on sesquiterpenes isolation, soaking the leaves in hexane for one week and then partitioned with hexane, dichloromethane, ethyl acetate and methanol. Duc Dat et al. (2019) separated megastigmanes by extracting with 95% methanol and then partitioning with dichloromethane, and ethyl acetate, and each fraction was further separated using different solvent combinations. Finally, De Marino et al. (2004, 2005) identified many compounds among sesquiterpenes and megastigmanes which they extracted using methanol, and then partitioned using n-hexane, tetrachloromethane, chloroform, and n-butanol. Then, the polar extracts were usually analyzed by NMR or HPLC-MS (Table 3).

Most abundant metabolites belong to the classes of hydroxycinnamic acids, flavonoids, sesquiterpenes and megastigmanes.

Hydroxycinnamic acids are molecules formed by C6 and C3 structures linked together, usually creating a structure with a benzene and a three-carbon side chain. Their importance is related to the ability to help plants in several developmental processes and, moreover, they are used by plants to withstand plant stresses thanks to their antioxidant properties. Concerning human nutrition, they are important in cardiovascular diseases, diabetes, and cancer prevention. In *L. nobilis* leaves, the most abundant hydroxycinnamic acids are Caffeic Acid, Chlorogenic Acid, p-Coumaric Acid, Cinnamic acid, Sinapic acid and Ferulic acid. They were found to range between 22.7 and 607 μg/g of dried leaves, with Sinapic acid showing the highest registered quantity, as observed in the study by Stefanova et al. (2020) (Table 3).

Sesquiterpenes have been isolated from the leaves extracts by many research groups (Matsuda et al.

Table 2 Main organic compounds isolated by GC–MS from essential oils of *L. nobilis* leaves

Compounds	Quantity (%)	References
(±)-Dehydrocostus Lactone	Cultivated: 0.541	Conforti et al. (2006)
(3E,5E,8Z)-3,7,11-Trimethyl-1,3,5,8,10-Dodecapentanene	Cultivated: 0.604	Conforti et al. (2006)
(3α S-(3α,6α,9α,9β))-Azuleno(4,5-β)Furan-2(3H)-One	Cultivated: 7.561	Conforti et al. (2006)
(3β,24S)-Stigmast-5-En-3-Ol	Wild: 7.182	Conforti et al. (2006)
	Cultivated: 4.626	
(5,8-Dihydro-6-Methyl-5,8-Etheno-4H-3α -Azaazulen-4-Yliden) Acetonitrile	Cultivated: 0.540	Conforti et al. (2006)
(E)-2-hexenal	Old: 0.1	Kilic et al. (2004)
	Young: 0.2	
(E)-2-hexenol	Young: 0.1	Kilic et al. (2004)
(E)-β-Ocimene	0.2	Caputo et al. (2017)
(E)-sabinene hydrate	Old: 0.5	Kilic et al. (2004)
	Young: 0.3	
(E)-sabinene hydrate acetate	Young: 0.6	Kilic et al. (2004)
(E,Z)-1,2-diethylidenecyclopentane	0.2	Belasli et al. (2020)
(Z)-3-hexenal	Old: 0.2	Kilic et al. (2004)
	Young: 0.3	
(Z)-3-hexenol	Old: 0.4	Kilic et al. (2004)
	Young: 0.2	
(Z)-β-Ocimene	0.2	Caputo et al. (2017)
(Z)-sabinene hydrate	Old: 0.4	Kilic et al. (2004)
	Young: 0.1	
1,3-Pentadiene	Morocco: 0.02	Jemâa et al. (2012)
1,8-Cineole	60.4	Evrendilek (2015)
	Greece: 30.8	Stefanova et al. (2020)
	Georgia: 29.2	
	Tunisia: 24.55	Jemâa et al. (2012)
	Algeria: 34.62	
	Morocco: 38.86	
	31.9	Caputo et al. (2017)
	SFME: 30.9	Bendjersi et al. (2016)
	HD: 26.4	
	33.4	Ivanović (2010)
	57.4	Tabanca et al. (2013)
	Fruits: 33.33	Fidan et al. (2019)
	Twigs: 48.53	
	Leaves: 41.02	
	40.58	Nafis et al. (2020)
	0.4	Peixoto et al. (2017)
	Serbian: 40.51	Riabov et al. (2020)
	Russian: 27.95	
	35.5	Belasli et al. (2020)
	39,76	Boulila et al. (2015)
	SDE: 33.28	Diaz-Maroto et al. (2002)
	SPME: 43.56	
	Old: 32.1	Kilic et al. (2004)
	Young: 24.2	
12-Nor-caryophyll-5-en-2-one	0.2	Belasli et al. (2020)
14-Methyl-Pentadecanoic Acid, Methyl Ester	Cultivated: 1.497	Conforti et al. (2006)
1-Bornyl Acetate	Morocco: 0.52	Jemâa et al. (2012)
1-Hexadecene	Wild: 1.905	Conforti et al. (2006)

Table 2 continued

Compounds	Quantity (%)	References
1-Octadecene	Cultivated: 0.314	Conforti et al. (2006)
1-α-Terpineol	Algeria: 0.04	Jemâa et al. (2012)
	Cultivated: 1.421	Conforti et al. (2006)
2-(1E)-Propenyl-Phenol	0.1	Caputo et al. (2017)
2-(4-Methoxyphenyl)-N,N,2-Trimethyl-1-Pyrrolamine	Cultivated: 4.041	Conforti et al. (2006)
2,3-Dehydro-1,8-Cineole	Serbian: 0.06	Riabov et al. (2020)
	Old: 0.1	Kilic et al. (2004)
2,3-Dimethoxy-1-Phenyl-5,5-Dimethylcyclopentene	Cultivated: 0.655	Conforti et al. (2006)
2,4-Diisopropenyl-1-Methyl-1-Vinyl-Cyclohexane	Cultivated: 0.539	Conforti et al. (2006)
2,6-Dimethyl-1,7-octa-	Old: 0.1	Kilic et al. (2004)
2-Acetoxy-1,8-cineole	Old: 0.1	Kilic et al. (2004)
	Young: 0.3	
2-Bornene	Russian: 0.10	Riabov et al. (2020)
2-Carene	13.08	Cherrat et al. (2014)
	Morocco: 5.62	Jemâa et al. (2012)
	Russian: 3.72	Riabov et al. (2020)
2-Cyclohexen-1-Ol	Tunisia: 0.08	Jemâa et al. (2012)
2-Hydroxy-1,8-cineole	Old: 0.1	Kilic et al. (2004)
2-Menthene	Russian: 0.11	Riabov et al. (2020)
2-Naphthalenemethanol	Tunisia: 0.50	Jemâa et al. (2012)
2-Nonanone	SFME: 0.1	Bendjersi et al. (2016)
	HD: 0.1	
2-Norbornanone	Tunisia: 1.20	Jemâa et al. (2012)
2-Pinen-10-Ol	Tunisia: 0.14	Jemâa et al. (2012)
2-Undecanone	Tunisia: 0.09	Jemâa et al. (2012)
	Morocco: 0.06	
3-Carene	0.21	Cherrat et al. (2014)
	1.14	Nafis et al. (2020)
	Serbian: 0.75	Riabov et al. (2020)
	Russian: 0.09	
	1.45	Boulila et al. (2015)
3-Hydroxy-1,8-cineole	Old: 0.1	Kilic et al. (2004)
3-Hydroxy-5,7-Dimethoxy-2-Methyl-1,4-Naphthoquinone	Cultivated: 0.565	Conforti et al. (2006)
4,8-Dimethyl-1,7-Nonadien-4-Ol	Serbian: 0.01	Riabov et al. (2020)
4-Isopropyl-1-Methyl-2-Cyclohexen-1-Ol	Serbian: 0.11	Riabov et al. (2020)
4-Thujen-2-α -yl Acetate	SFME: 0.3	Bendjersi et al. (2016)
	HD: 0.1	
	0.28	Ivanović (2010)
	Old: 0.1	Kilic et al. (2004)
6,10,11,11-Tetramethyl-Tricyclo(5.3.0.1(2,3))Undec-7-Ene	Cultivated: 0.562	Conforti et al. (2006)
9,12,15-Octadecatrienoic Acid, Methyl Ester	Wild: 2.561	Conforti et al. (2006)
9-Octadecenoic Acid, Methyl Ester	Cultivated: 0.446	Conforti et al. (2006)
Aceteugenol	SFME: 0.2	Bendjersi et al. (2016)
Allo Spathullenol	Algeria: 0.08	Jemâa et al. (2012)
Allo-Aromadendrene	Serbian: 0.04	Riabov et al. (2020)
	0.1	Caputo et al. (2017)
Allo-Ocimene	0.2	Caputo et al. (2017)
Anethole	0.4	Peixoto et al. (2017)
Aromadendrene	Algeria: 0.23	Jemâa et al. (2012)
Benzene	Tunisia: 0.28	Jemâa et al. (2012)
	Algeria: 0.24	

Table 2 continued

Compounds	Quantity (%)	References
Bicyclo(4.4.0)Dec-1-En,2-Isopropyl-5 -Methyl-9-Methylene	Cultivated: 0.875	Conforti et al. (2006)
Bicyclogermacrene	SFME: 0.2	Bendjersi et al. (2016)
	HD: 0.2	
	0.36	Ivanović (2010)
	Leaves: 0.16	Fidan et al. (2019)
	0.2	Belasli et al. (2020)
Borneol	SFME: 0.1	Bendjersi et al. (2016)
	HD: 0.1	
	0.4	Belasli et al. (2020)
	Old: 0.3	Kilic et al. (2004)
Bornyl Acetate	Greece: 1.2	Stefanova et al. (2020)
	Fruits: 4.38	Fidan et al. (2019)
	Twigs: 0.52	
	Leaves: 0.65	
	SFME: 1.2	Bendjersi et al. (2016)
	HD: 0.2	
	0.47	Ivanović (2010)
	Serbian: 0.33	Riabov et al. (2020)
	Russian: 0.12	
	0.2	Tabanca et al. (2013)
	SDE: 1.67	Diaz-Maroto et al. (2002)
	SPME: 2.27	
	Old: 0.6	(Kilic et al. 2004)
	Young: 1.1	
Calamenene	Serbian: 0.04	Riabov et al. (2020)
Calarene	Cultivated: 0.324	Conforti et al. (2006)
Camphene	Greece: 0.6	Stefanova et al. (2020)
	Georgia: 0.2	
	Fruits: 4.33	Fidan et al. (2019)
	Twigs: 0.30	
	Leaves: 0.18	
	Tunisia: 0.41	Jemâa et al. (2012)
	Algeria: 0.25	
	Morocco: 0.42	
	Tunisia: 7.21	Jemâa et al. (2012)
	Algeria: 8.91	
	0.8	Caputo et al. (2017)
	SFME: 0.6	Bendjersi et al. (2016)
	HD: 0.3	
	0.30	Ivanović (2010)
	Serbian: 0.41	Riabov et al. (2020)
	Russian: 0.48	
	13.4	Belasli et al. (2020)
	0.51	Boulila et al. (2015)
	SDE: 1.06	Diaz-Maroto et al. (2002)
	Old: 0.6	Kilic et al. (2004)
	Young: 1.1	
Camphor	Tunisia: 2.66	Jemâa et al. (2012)
	0.2	Caputo et al. (2017)
	Russian: 0.01	Riabov et al. (2020)

Table 2 continued

Compounds	Quantity (%)	References
Carveone	Russian: 0.03	Riabov et al. (2020)
Caryophylla-4(12),8(13)-Dien-5α-Ol	SFME: 1.6	Bendjersi et al. (2016)
Caryophyllene epoxide	Algeria: 0.47	Jemâa et al. (2012)
Caryophyllene oxide	Greece: 0.4	Stefanova et al. (2020)
	Georgia: 0.4	
	Fruits: 0.61	Fidan et al. (2019)
	Twigs: 0.41	
	Leaves: 0.34	
	0.3	Caputo et al. (2017)
	SFME: 0.1	Bendjersi et al. (2016)
	HD: 1.8	
	0.26	Ivanović (2010)
	0.3	Peixoto et al. (2017)
	Serbian: 0.20	Riabov et al. (2020)
	0.1	Tabanca et al. (2013)
	0.6	Belasli et al. (2020)
	0,48	Boulila et al. (2015)
Cedren-13-Ol Acetate < 8- >	Fruits: 0.97	Fidan et al. (2019)
Chavicol	10.2	Peixoto et al. (2017)
	Serbian: 0.04	Riabov et al. (2020)
Cinnamic acid	0.3	Belasli et al. (2020)
Cinnamic Acidethyl Ester	Algeria: 0.11	Jemâa et al. (2012)
Cinnamyl Acetate	Morocco: 0.06	Jemâa et al. (2012)
	Cultivated: 0.276	Conforti et al. (2006)
	SFME: 0.2	Bendjersi et al. (2016)
	HD: 0.2	
	Serbian: 0.07	Riabov et al. (2020)
Cinnamyl Alcohol	Serbian: 0.02	Riabov et al. (2020)
cis-Carveol	0.2	Caputo et al. (2017)
cis-Cinnamaldehyde	Russian: 0.01	Riabov et al. (2020)
cis-Farmesol	0.18	Cherrat et al. (2014)
cis-Geraniol	Tunisia: 0.10	Jemâa et al. (2012)
	Algeria: 0.08	
	Morocco: 0.14	
cis-Ocimene	3.06	Cherrat et al. (2014)
cis-Piperitol	Serbian: 0.03	Riabov et al. (2020)
cis-p-Mentha-1(7),8-Dien-2-Ol	0.1	Caputo et al. (2017)
cis-p-Mentha-1(7),8-Diene-2-Ol	0.3	Tabanca et al. (2013)
cis-Sabinene Hydrate	Leaves: 0.62	Fidan et al. (2019)
	Morocco: 0.08	Jemâa et al. (2012)
	0.3	Caputo et al. (2017)
	SFME: 0.7	Bendjersi et al. (2016)
	HD: 0.5	
	0.30	Ivanović (2010)
	0.6	Tabanca et al. (2013)
cis-Tagetone	Serbian: 0.01	Riabov et al. (2020)
cis-Thujopsene	0.2	Caputo et al. (2017)
cis-β-Ocimene	Fruits: 0.16	Fidan et al. (2019)
	SFME: 0.1	Bendjersi et al. (2016)
	Serbian: 0.01	Riabov et al. (2020)
	Russian: 0.01	

Table 2 continued

Compounds	Quantity (%)	References
Copaene	Serbian: 0.02	Riabov et al. (2020)
Costunolide	Cultivated: 2.342	Conforti et al. (2006)
Cumin Alcohol	0.1	Tabanca et al. (2013)
Cyclodecene	Tunisia: 0.08	Jemâa et al. (2012)
Cyclododecyne	Wild: 0.395	Conforti et al. (2006)
Cyclofenchene	2.03	Nafis et al. (2020)
Cyclohexadecane	Cultivated: 0.347	Conforti et al. (2006)
Cyclohexanol,3-Ethenyl-3-Meythyl-2 -(1-Methylethenyl)-6-(1-Methylethyl)	Wild: 0.823	Conforti et al. (2006)
Cyclooctacosane	Cultivated: 0.704	Conforti et al. (2006)
Cyclopentane	Tunisia: 0.11	Jemâa et al. (2012)
	Algeria: 0.10	
Cyclosativene	0.1	Caputo et al. (2017)
Cyclosativene	Russian: 0.01	Riabov et al. (2020)
Cyclotetracosane	Cultivated: 2.744	Conforti et al. (2006)
D-Camphene	0.55	Cherrat et al. (2014)
Decanal	SFME: 0.1	Bendjersi et al. (2016)
Dehydro-1,8-Cineole	0.21	Ivanović (2010)
	0.9	Tabanca et al. (2013)
Dehydrocostus lactone	51.69	Pacifico et al. (2013)
Dehydrosanssurea Lactone	Cultivated: 1.638	Conforti et al. (2006)
Diene-3,6-diol spirafoliolide	Old: 2.2	Kilic et al. (2004)
	Young: 3.7	
Dihydromethylisoeugenol	Russian: 0.01	Riabov et al. (2020)
Elemicin	Georgia: 1.1	Stefanova et al. (2020)
	Morocco: 0.14	Jemâa et al. (2012)
	Wild: 4.958	Conforti et al. (2006)
	Cultivated: 0.390	
	1.27	Nafis et al. (2020)
	0.5	Caputo et al. (2017)
	SFME: 0.5	Bendjersi et al. (2016)
	HD: 0.7	
	Serbian: 0.62	Riabov et al. (2020)
	0.6	Belasli et al. (2020)
	SDE: 0.43	Diaz-Maroto et al. (2002)
	1.19	Pacifico et al. (2013)
	4.41	(Nabiha et al. 2009)
Elemol	SFME: 0.1	Bendjersi et al. (2016)
	HD: 0.1	
Endobornyl Acetate	Algeria: 0.15	Jemâa et al. (2012)
Endrine	0.16	Cherrat et al. (2014)
Epi-Bicyclosesquihellandrene	Serbian: 0.07	Riabov et al. (2020)
Epizonaren	Algeria: 0.06	Jemâa et al. (2012)
Eremanthin	Cultivated: 5.186	Conforti et al. (2006)
	3.39	Pacifico et al. (2013)
Eremoligenol	0.1	Caputo et al. (2017)
Eremophilene	Tunisia: 0.67	Jemâa et al. (2012)
	Wild: 0.812	Conforti et al. (2006)
	Cultivated: 0.413	
Estragole	Algeria: 0.12	Jemâa et al. (2012)
	Russian: 0.02	Riabov et al. (2020)

Table 2 continued

Compounds	Quantity (%)	References
Ethyl Cinnamate	Wild: 1.414	Conforti et al. (2006)
	Morocco: 0.25	Jemâa et al. (2012)
Ethyl Hexanol	0.4	Peixoto et al. (2017)
Ethyl Isovalerate	0.1	Caputo et al. (2017)
Eucalyptol	3.25	Pacifico et al. (2013)
Eudesmol	Wild: 1.357	Conforti et al. (2006)
	Cultivated: 3.903	
Eugenol	0.5	Evrendilek (2015)
	Greece: 2.7	Stefanova et al. (2020)
	Georgia: 0.8	
	Fruits: 0.21	Fidan et al. (2019)
	Twigs: 0.33	
	Leaves: 1.47	
	Tunisia: 2.18	Jemâa et al. (2012)
	Morocco: 1.42	
	Wild: 3.079	Conforti et al. (2006)
	Cultivated: 1.986	
	5.14	Nafis et al. (2020)
	1.6	Caputo et al. (2017)
	SFME: 3.6	Bendjersi et al. (2016)
	HD: 1.2	
	1.77	Ivanović (2010)
	Serbian: 2.10	Riabov et al. (2020)
	Russian: 0.47	
	0.1	Tabanca et al. (2013)
	1.0	Belasli et al. (2020)
	0,07	Boulila et al. (2015)
	SDE: 3.00	Diaz-Maroto et al. (2002)
	SPME: 1.23	
	Old: 1.6	Kilic et al. (2004)
	Young: 0.1	
	2.04	Pacifico et al. (2013)
	7.42	Nabiha et al. (2009)
eugenol methyl ether	Old: 1.2	Kilic et al. (2004)
	Young: 0.2	
Eugenyl Acetate	Russian: 1.37	Riabov et al. (2020)
Exo-2-Hydroxycineole Acetate	0.20	Ivanović (2010)
Exo-Fenchol	0.1	Caputo et al. (2017)
Geraniol	Serbian: 0.05	Riabov et al. (2020)
	Russian: 0.25	
Geraniol Acetate	Tunisia: 0.08	Jemâa et al. (2012)
Germacrene	Morocco: 0.1	Jemâa et al. (2012)
	Serbian: 0.02	Riabov et al. (2020)
Germacrene A	Old: 0.4	Kilic et al. (2004)
	Young: 1.2	

Table 2 continued

Compounds	Quantity (%)	References
Germacrene D	Greece: 0.3	Stefanova et al. (2020)
	Georgia: 0.1	
	Leaves: 0.25	Fidan et al. (2019)
	SFME: 0.1	Bendjersi et al. (2016)
	HD: 0.1	
	Algeria: 0.18	Jemâa et al. (2012)
	Old: 0.4	Kilic et al. (2004)
	Young: 0.6	
Germacrene-D-4-Ol	SFME: 0.2	Bendjersi et al. (2016)
	Serbian: 0.10	Riabov et al. (2020)
	Old: 0.2	Kilic et al. (2004)
	Young: 0.2	
Globulol	Morocco: 0.23	Jemâa et al. (2012)
Heptanen	Tunisia: 0.03	Jemâa et al. (2012)
	Algeria: 0.03	
homovanillyl alcohol	Young: 0.2	Kilic et al. (2004)
Isoborneol	0.5	Caputo et al. (2017)
Isobornyl Acetate	Russian: 0.05	Riabov et al. (2020)
Isoelemicin	Serbian: 0.10	Riabov et al. (2020)
Isoeugenol	53.5	Peixoto et al. (2017)
	Morocco: 0.03	Jemâa et al. (2012)
	Old: 0.1	Kilic et al. (2004)
	Young: 0.6	
Iso-Isopulegol	0.6	Caputo et al. (2017)
Isolimonene	Russian: 0.51	Riabov et al. (2020)
Isolongifolene	Serbian: 0.05	Riabov et al. (2020)
Isospathulenol	Tunisia: 0.12	Jemâa et al. (2012)
	Algeria: 0.12	
Isovaleraldehyde	Tunisia: 9.65	Jemâa et al. (2012)
	Algeria: 8.82	
	Morocco: 10.47	
iso-Verbanol Acetate	0.3	Caputo et al. (2017)
Junipene	0.24	Cherrat et al. (2014)
Ledene	Tunisia: 0.70	Jemâa et al. (2012)
Ledol	Fruits: 0.31	Fidan et al. (2019)
	Twigs: 0.27	
	Leaves: 0.39	
	Algeria: 0.13	Jemâa et al. (2012)
Lepidozene	Algeria: 0.39	Jemâa et al. (2012)
Limonene	Fruits: 2.25	Fidan et al. (2019)
	Twigs: 1.68	
	Leaves: 0.04	
	2.4	Peixoto et al. (2017)
	Serbian: 0.39	Riabov et al. (2020)
	Russian: 0.28	
	1.0	Tabanca et al. (2013)
	1.3	Belasli et al. (2020)
	Old: 2.5	Kilic et al. (2004)
	Young: 2.0	
	2.49	Pacifico et al. (2013)

Table 2 continued

Compounds	Quantity (%)	References
Limonene-β-Phellandrene	1.59	Ivanović (2010)
Linalool	0.7	Evrendilek (2015)
	Georgia: 3.8	Stefanova et al. (2020)
	Tunisia: 17.67	Jemâa et al. (2012)
	Algeria: 12.57	
	Morocco: 9.45	
	6.81	Nafis et al. (2020)
	0.1	Caputo et al. (2017)
	SFME: 9.5	Bendjersi et al. (2016)
	HD: 4.9	
	16.0	Ivanović (2010)
	2.6	Peixoto et al. (2017)
	Serbian: 4.72	Riabov et al. (2020)
	Russian: 4.50	
	0.3	Tabanca et al. (2013)
	11.4	Belasli et al. (2020)
	10,03	Boulila et al. (2015)
	Old: 0.7	Kilic et al. (2004)
	Young: 1.5	
	SDE: 24.53	Diaz-Maroto et al. (2002)
	SPME: 26.70	
Linalyl Acetate	Tunisia: 0.69	Jemâa et al. (2012)
	Algeria: 0.41	
	SFME: 0.1	Bendjersi et al. (2016)
	HD: 0.1	
	0.34	Ivanović (2010)
	Serbian: 0.18	Riabov et al. (2020)
	SDE: 0.46	Diaz-Maroto et al. (2002)
	SPME: 0.80	
	Old: 0.1	Kilic et al. (2004)
Linoleic acid, methyl ester	Cultivated: 0.236	Conforti et al. (2006)
Longicyclene	0.2	Caputo et al. (2017)
Longifolene	0.2	Belasli et al. (2020)
L-Phellandrene	Morocco: 0.19	Jemâa et al. (2012)
m-Camphorene	2.2	Peixoto et al. (2017)
m-Cymene	0.8	Belasli et al. (2020)
Menthene	Russian: 0.02	Riabov et al. (2020)
Methyl cis-Isoeugenol	Morocco: 0.16	Jemâa et al. (2012)

Table 2 continued

Compounds	Quantity (%)	References
Methyl Eugenol	1.06	Cherrat et al. (2014)
	Wild: 21.345	Conforti et al. (2006)
	Cultivated: 2.908	
	SFME: 6.2	Bendjersi et al. (2016)
	HD: 5.1	
	5.32	Ivanović (2010)
	Greece: 3.6	Stefanova et al. (2020)
	Georgia: 8.1	
	Fruits: 1.58	Fidan et al. (2019)
	Twigs: 6.62	
	Leaves: 6.03	
	8.72	Nafis et al. (2020)
	Serbian: 9.20	Riabov et al. (2020)
	Russian: 4.89	
	0.9	Tabanca et al. (2013)
	3.3	Caputo et al. (2017)
	Tunisia: 12.40	Jemâa et al. (2012)
	Algeria: 2.84	
	Morocco: 3.93	
	7.8	Belasli et al. (2020)
	2,98	Boulila et al. (2015)
	SDE: 4.64	Diaz-Maroto et al. (2002)
	SPME: 3.12	
	19.57	Nabiha et al. (2009)
	9.51	Pacifico et al. (2013)
Methyl Isoeugenol	1.33	Cherrat et al. (2014)
	2.5	Peixoto et al. (2017)
	Serbian: 0.36	Riabov et al. (2020)
Methyl Pentanoate	0.1	Caputo et al. (2017)
Myrcene	0.2	Belasli et al. (2020)
	Old: 0.9	Kilic et al. (2004)
	Young: 1.4	
Myrcenone	HD: 0.1	Bendjersi et al. (2016)
Myrtenal	0.8	Tabanca et al. (2013)
Myrtenol	0.39	Cherrat et al. (2014)
	HD: 0.5	Bendjersi et al. (2016)
	0.3	Tabanca et al. (2013)
	Russian: 0.04	Riabov et al. (2020)
Naphtalene	Tunisia: 0.27	Jemâa et al. (2012)
	Algeria: 0.19	
n-Docosane	Greece: 0.7	Stefanova et al. (2020)
	Georgia: 0.2	
	Fruits: 0.21	Fidan et al. (2019)
	Twigs: 0.18	
	Leaves: 0.26	
Neo-3-Thujanol Acetate	0.4	Caputo et al. (2017)
Neoiso-Isopulegol	2.5	Caputo et al. (2017)

Table 2 continued

Compounds	Quantity (%)	References
Neophytadiene	Wild: 1.210	Conforti et al. (2006)
	Cultivated: 0.466	
	Old: 0.3	Kilic et al. (2004)
	Young: 0.2	
Nerol	SFME: 0.1	Bendjersi et al. (2016)
	HD: 0.1	
	0.19	Ivanović (2010)
	Serbian: 0.19	Riabov et al. (2020)
	Russian: 0.14	
	0.2	Belasli et al. (2020)
	SDE: 0.29	Díaz-Maroto et al. (2002)
	SPME: 0.09	
Neryl Acetate	SFME: 0.4	Bendjersi et al. (2016)
	HD: 0.1	
	Morocco: 0.13	Jemâa et al. (2012)
n-Heneicosane	Greece: 0.6	Stefanova et al. (2020)
	Georgia: 0.2	
	Fruits: 0.19	Fidan et al. (2019)
	Twigs: 0.16	
	Leaves: 0.24	
n-Heptacosane	Greece: 0.9	Stefanova et al. (2020)
	Georgia: 0.3	
	Fruits: 0.33	Fidan et al. (2019)
	Twigs: 0.28	
	Leaves: 0.40	
n-Heptadecane	Greece: 0.2	Stefanova et al. (2020)
	Georgia: 0.1	
n-Hexacosane	Greece: 0.8	Stefanova et al. (2020)
	Georgia: 0.3	
	Fruits: 0.39	Fidan et al. (2019)
	Twigs: 0.34	
	Leaves: 0.49	
n-Octacosane	Greece: 0.3	Stefanova et al. (2020)
	Georgia: 0.1	
	Fruits: 0.26	Fidan et al. (2019)
	Twigs: 0.23	
	Leaves: 0.33	
n-Pentacosane	Greece: 0.5	Stefanova et al. (2020)
	Georgia: 0.2	
	Fruits: 0.24	Fidan et al. (2019)
	Twigs: 0.21	
	Leaves: 0.30	
n-Tetracosane	Greece: 0.3	Stefanova et al. (2020)
	Georgia: 0.1	
	Fruits: 0.16	Fidan et al. (2019)
	Twigs: 0.15	
	Leaves: 0.20	

Table 2 continued

Compounds	Quantity (%)	References
n-Tricosane	Greece: 0.4	Stefanova et al. (2020)
	Georgia: 0.1	
	Fruits: 0.19	Fidan et al. (2019)
	Twigs: 0.17	
	Leaves: 0.23	
Octan-3-One	0.8	Peixoto et al. (2017)
o-Cymene	0.3	Caputo et al. (2017)
Palmitic Acid, Methyl Ester	Wild: 1.403	Conforti et al. (2006)
Patchoulene	0.10	Cherrat et al. (2014)
p-Camphorene	0.8	Peixoto et al. (2017)
p-Cymen-7-Ol	Serbian: 0.02	Riabov et al. (2020)
p-Cymen-8-Ol	0.2	Tabanca et al. (2013)
p-Cymene	Twigs: 1.00	Fidan et al. (2019)
	Leaves: 0.18	
	HD: 0.2	Bendjersi et al. (2016)
	0.41	Ivanović (2010)
	0.8	Peixoto et al. (2017)
	Serbian: 1.48	Riabov et al. (2020)
	Russian: 2.30	
	2.2	Tabanca et al. (2013)
	0.2	Belasli et al. (2020)
	Old: 0.1	Kilic et al. (2004)
Pentane	Tunisia: 0.47	Jemâa et al. (2012)
	Algeria: 2.14	
Phellandral	0.4	Tabanca et al. (2013)
Phenol	Tunisia: 0.30	Jemâa et al. (2012)
	Algeria: 1.73	
Phytol	Greece: 1.5	Stefanova et al. (2020)
	Georgia: 0.1	
	Fruits: 0.21	Fidan et al. (2019)
	Twigs: 0.18	
	Leaves: 0.26	
	Wild: 3.366	Conforti et al. (2006)
	Cultivated: 1.811	
Pinocarvone	HD: 0.6	Bendjersi et al. (2016)
	0.3	Tabanca et al. (2013)
p-Mentha-1,4-Diene-7-Ol	Serbian: 0.14	Riabov et al. (2020)
p-Mentha-1,5-Dien-7-Ol	0.2	Tabanca et al. (2013)
Propyl Hexanoate	Serbian: 0.01	Riabov et al. (2020)
Pulegone	Morocco: 0.05	Jemâa et al. (2012)
Sabinene	5.13	Nafis et al. (2020)
	12.7	Evrendilek (2015)
	Greece: 7.9	Stefanova et al. (2020)
	Georgia: 12.2	
	Fruits: 6.30	Fidan et al. (2019)
	Twigs: 3.33	
	Leaves: 8.82	
	12.2	Caputo et al. (2017)
	SFME: 9.6	Bendjersi et al. (2016)
	HD: 9	
	6.91	Ivanović (2010)

Table 2 continued

Compounds	Quantity (%)	References
	Serbian: 0.17	Riabov et al. (2020)
	Russian: 0.07	
	5.7	Tabanca et al. (2013)
	4.8	Belasli et al. (2020)
	7.26	Boulila et al. (2015)
	SDE: 5.80	Diaz-Maroto et al. (2002)
	SPME: 2.48	
	Old: 7.6	Kilic et al. (2004)
	Young: 7.1	
Sesquiterpene	Young: 0.3	Kilic et al. (2004)
Sesquiterpene (MW 204)	Old: 0.1	Kilic et al. (2004)
	Young: 0.2	
Sesquiterpene (MW 204)	Old: 0.1	Kilic et al. (2004)
	Young: 0.1	
Sesquiterpene lactone (MW230)	Old: 1.1	Kilic et al. (2004)
	Young: 0.5	
Sesquiterpene lactone (MW230)	Old: 6.6	Kilic et al. (2004)
	Young: 8.2	
Sesquiterpene lactone (MW230)	Old: 1.5	Kilic et al. (2004)
	Young: 1.7	
Sesquiterpene lactone (MW246)	Young: 1.2	Kilic et al. (2004)
Seychellene	0.38	Cherrat et al. (2014)
Spathulenol	Greece: 0.4	Stefanova et al. (2020)
	Georgia: 0.2	
	Tunisia: 1.12	Jemâa et al. (2012)
	Algeria: 1.66	
	Morocco: 0.16	
	0.4	Caputo et al. (2017)
	SFME: 0.1	Bendjersi et al. (2016)
	HD: 0.7	
	0.27	Ivanović (2010)
	Serbian: 0.41	Riabov et al. (2020)
	Fruits: 0.25	Fidan et al. (2019)
	Twigs: 0.21	
	Leaves: 0.31	
	Wild: 4.629	Conforti et al. (2006)
	Cultivated: 1.882	
	0.9	Belasli et al. (2020)
	0,82	Boulila et al. (2015)
	SDE: 0.55	Diaz-Maroto et al. (2002)
	SPME: 0.41	
	1.75	Pacifico et al. (2013)
Spirolepechinene	0.1	Caputo et al. (2017)
Squalene	Greece: 0.9	Stefanova et al. (2020)
	Georgia: 0.3	
	Fruits: 0.41	Fidan et al. (2019)
	Twigs: 0.35	
	Leaves: 0.51	
Tepinen-1-Ol	Tunisia: 1.47	Jemâa et al. (2012)
	SFME: 0.1	Bendjersi et al. (2016)
	HD: 0.1	

Table 2 continued

Compounds	Quantity (%)	References
Terpinen-4-Ol	2.0	Evrendilek (2015)
	Greece: 6.0	Stefanova et al. (2020)
	Georgia: 1.8	
	4.07	Nafis et al. (2020)
	2.38	Ivanović (2010)
	0.6	Peixoto et al. (2017)
	4.0	Tabanca et al. (2013)
	Fruits: 0.85	Fidan et al. (2019)
	Twigs: 3.25	
	Leaves: 2.35	
	SFME: 1.2	Bendjersi et al. (2016)
	HD: 1.4	
	Morocco: 1.52	Jemâa et al. (2012)
	Cultivated: 0.431	Conforti et al. (2006)
	Serbian: 2.36	Riabov et al. (2020)
	3.2	Belasli et al. (2020)
	0,87	Boulila et al. (2015)
	SDE: 2.28	Diaz-Maroto et al. (2002)
	SPME: 0.86	
	Old: 0.7	Kilic et al. (2004)
	Young: 0.3	
	6.44	Nabiha et al. (2009)
Terpinene	Algeria: 0.92	Jemâa et al. (2012)
Terpinene-4-Ol Acetate	Russian: 0.47	Riabov et al. (2020)
Terpinolene	0.33	Ivanović (2010)
	0.1	Tabanca et al. (2013)
	Young: 0.1	Kilic et al. (2004)
Terpinyl acetate	SDE: 8.16	Diaz-Maroto et al. (2002)
	SPME: 11.75	
Thuj-3-En-10-Al	0.5	Tabanca et al. (2013)
Thujopsan-2-Ol	0.1	Caputo et al. (2017)
Thymol	Fruits: 0.20	Fidan et al. (2019)
	Twigs: 0.70	
	Leaves: 0.15	
	Cultivated: 0.842	Conforti et al. (2006)
Toluene	Old: 0.1	Kilic et al. (2004)
	Young: 0.1	
Trans-B-Caryophyllene	Algeria: 0.74	Jemâa et al. (2012)
Trans-Carveol	HD: 0.1	Bendjersi et al. (2016)
	0.1	Tabanca et al. (2013)
Trans-Caryophyllene	2.74	Cherrat et al. (2014)
	Morocco: 0.05	Jemâa et al. (2012)
	Cultivated: 0.470	Conforti et al. (2006)
	SFME: 0.1	Bendjersi et al. (2016)
	HD: 0.2	
	Serbian: 0.34	Riabov et al. (2020)
Trans-Cinnamaldehyde	Russian: 0.19	Riabov et al. (2020)
Trans-Geraniol	SDE: 0.11	Diaz-Maroto et al. (2002)
Trans-Methyl Isoeugenol	0.84	Cherrat et al. (2014)
Trans-Ocimene	7.05	Cherrat et al. (2014)

Table 2 continued

Compounds	Quantity (%)	References
Trans-Pinocarveol	SFME: 0.1	Bendjersi et al. (2016)
	HD: 0.5	
	0.5	Tabanca et al. (2013)
Trans-Piperitol	Serbian: 0.13	Riabov et al. (2020)
Trans-p-Menth-2-En-1-Ol	SFME: 0.1	Bendjersi et al. (2016)
	HD: 0.3	
	0.2	Tabanca et al. (2013)
Trans-p-Mentha-1(7),8-Dien-2-Ol	0.3	Tabanca et al. (2013)
Trans-P-Mentha-2,8-Dien-1-Ol	0.5	Tabanca et al. (2013)
Trans-Sabinene Hydrate	0.39	Cherrat et al. (2014)
	Tunisia: 0.14	Jemâa et al. (2012)
	Algeria: 0.08	
	Morocco: 0.30	
	10.2	Caputo et al. (2017)
	0.6	Tabanca et al. (2013)
	0.3	Belasli et al. (2020)
Trans-Sabinene Hydrate Acetate	0.7	Caputo et al. (2017)
Trans-Sabinol	0.2	Caputo et al. (2017)
Trans-Thujan-4-ol	SDE: 0.43	Diaz-Maroto et al. (2002)
	SPME: 0.29	
Trans-β-Ocimene	Fruits: 0.72	Fidan et al. (2019)
Trans-B-Ocimene	HD: 0.1	Bendjersi et al. (2016)
	Serbian: 0.13	Riabov et al. (2020)
	Russian: 0.01	
Valencene	HD: 0.1	Bendjersi et al. (2016)
	Serbian: 0.05	Riabov et al. (2020)
	Russian: 0.03	
	0.2	Belasli et al. (2020)
Vanillin	Old: 0.1	Kilic et al. (2004)
Veridiflorol	Tunisia: 0.11	Jemâa et al. (2012)
	Algeria: 0.13	
Vertiverol	Morocco: 0.08	Jemâa et al. (2012)
Vinyl Amyl Carbinol	1.1	Peixoto et al. (2017)
Viridiflorol	0.2	Caputo et al. (2017)
Viridiflorol	SFME: 0.1	Bendjersi et al. (2016)
	HD: 0.4	
Vitamin E	Wild: 18.846	Conforti et al. (2006)
	Cultivated: 9.031	
Zeta-Fenchene	0.2	Belasli et al. (2020)
α-Amorphene	Algeria: 0.19	Jemâa et al. (2012)
	0.1	Caputo et al. (2017)
α-Berganotene	Algeria: 0.19	Jemâa et al. (2012)
α-Cadinene	Serbian: 0.02	Riabov et al. (2020)
α-Cadinol	Algeria: 0.15	Jemâa et al. (2012)
	SFME: 0.2	Bendjersi et al. (2016)
	HD: 0.4	
α-Calacorene	Serbian: 0.03	Riabov et al. (2020)
α-Caryophyllene	Tunisia: 0.08	Jemâa et al. (2012)
α-Copaen-11-Ol	Serbian: 0.04	Riabov et al. (2020)

Table 2 continued

Compounds	Quantity (%)	References
α-Copaene	0.3	Peixoto et al. (2017)
	Old: 0.1	Kilic et al. (2004)
	Young: 0.3	
α-Cubebene	Serbian: 0.02	Riabov et al. (2020)
α-Farnesene	0.3	Peixoto et al. (2017)
α-Fenchene	Russian: 1.33	Riabov et al. (2020)
α-Fenchyl Acetate	Tunisia: 0.40	Jemâa et al. (2012)
	Cultivated: 0.267	Conforti et al. (2006)
α-Guaiene	0.41	Cherrat et al. (2014)
	Tunisia: 0.10	Jemâa et al. (2012)
	Algeria: 0.8	
	Serbian: 0.25	Riabov et al. (2020)
	Old: 0.1	Kilic et al. (2004)
	Young: 0.1	
α-Gurjunene	Algeria: 0.10	Jemâa et al. (2012)
	Serbian: 0.02	Riabov et al. (2020)
α-Himachalene	0.17	Cherrat et al. (2014)
α-Humulene	0.3	Peixoto et al. (2017)
	Serbian: 0.48	Riabov et al. (2020)
α-Limonene Diepoxide	Russian: 0.02	Riabov et al. (2020)
α-Phellandrene	Greece: 0.3	Stefanova et al. (2020)
	Georgia: 0.8	
	Fruits: 5.18	Fidan et al. (2019)
	Twigs: 0.38	
	Leaves: 1.01	
	Algeria: 0.11	Jemâa et al. (2012)
	0.5	Caputo et al. (2017)
	SFME: 0.3	Bendjersi et al. (2016)
	HD: 0.4	
	0.17	Ivanović (2010)
	0.2	Peixoto et al. (2017)
	Serbian: 0.84	Riabov et al. (2020)
	0.6	Belasli et al. (2020)
	Old: 0.2	Kilic et al. (2004)
	Young: 0.1	
α-Pinene	Greece: 5.3	Stefanova et al. (2020)
	Georgia: 5.5	
	Fruits: 11.01	Fidan et al. (2019)
	Twigs: 2.94	
	Leaves: 2.56	
	Tunisia: 2.52	Jemâa et al. (2012)
	Algeria: 4.58	
	Morocco:4.31	
	2.85	Nafis et al. (2020)
	5.8	Caputo et al. (2017)
	SFME: 4.6	Bendjersi et al. (2016)
	HD: 9.2	
	4.39	Ivanović (2010)
	0.3	Peixoto et al. (2017)
	Serbian: 4.45	Riabov et al. (2020)
	Russian: 31.97	

Table 2 continued

Compounds	Quantity (%)	References
	3.8	Tabanca et al. (2013)
	6.1	Evrendilek (2015)
	4.7	Belasli et al. (2020)
	10.17	Boulila et al. (2015)
	SDE: 4.33	Diaz-Maroto et al. (2002)
	SPME: 0.85	
	Old: 3.9	Kilic et al. (2004)
	Young: 5.0	
α-Pinene Oxide	Russian: 0.02	Riabov et al. (2020)
α-Terpinen-7-Al	0.3	Caputo et al. (2017)
α-Terpinene	Fruits: 0.22	Fidan et al. (2019)
	Twigs: 0.89	
	Leaves: 0.52	
	Tunisia: 0.11	Jemâa et al. (2012)
	Algeria: 0.42	
	Morocco: 0.19	
	0.6	Caputo et al. (2017)
	0.42	Ivanović (2010)
	0.2	Tabanca et al. (2013)
	12.6	Evrendilek (2015)
	SFME: 0.3	Bendjersi et al. (2016)
	HD: 0.3	
α-Terpineol	Greece: 8.0	Stefanova et al. (2020)
	Georgia: 1.7	
	Fruits: 1.55	Fidan et al. (2019)
	Twigs: 1.73	
	Leaves: 3.11	
	Tunisia: 1.29	Jemâa et al. (2012)
	Algeria: 0.90	
	Marocco: 5.83	
	5.60	Nafis et al. (2020)
	3.3	Caputo et al. (2017)
	SFME: 7.6	Bendjersi et al. (2016)
	HD: 3.3	
	2.83	Ivanović (2010)
	0.3	Peixoto et al. (2017)
	Serbian: 15.46	Riabov et al. (2020)
	Russian: 10.28	
	3.8	Tabanca et al. (2013)
	2.2	Belasli et al. (2020)
	1,35	Boulila et al. (2015)
	SDE: 4.09	Diaz-Maroto et al. (2002)
	SPME: 4.95	
	Old: 1.3	Kilic et al. (2004)
	Young: 1.8	
	3.21	Nabiha et al. (2009)

Table 2 continued

Compounds	Quantity (%)	References
α-Terpinolene	Algeria: 0.15	Jemâa et al. (2012)
	Morocco: 0.20	
	Serbian: 0.43	Riabov et al. (2020)
	Russian: 1.34	
	SFME: 0.3	Bendjersi et al. (2016)
	HD: 0.2	
	0.5	Belasli et al. (2020)
	SDE: 0.16	Diaz-Maroto et al. (2002)
α-Terpinyl Acetate	Greece: 14.9	Stefanova et al. (2020)
	Georgia: 22.6	
	Fruits: 10.30	Fidan et al. (2019)
	Twigs: 13.09	
	Leaves: 14.44	
	Cultivated: 7.145	Conforti et al. (2006)
	12.64	Nafis et al. (2020)
	5.9	Caputo et al. (2017)
	SFME: 7.9	Bendjersi et al. (2016)
	HD: 9.5	
	13.8	Ivanović (2010)
	7.0	Tabanca et al. (2013)
	13,35	Boulila et al. (2015)
	Old: 6.5	Kilic et al. (2004)
	Old: 4.8	
	28.43	Nabiha et al. (2009)
	8.25	Pacifico et al. (2013)
α-Thujene	Greece: 0.3	Stefanova et al. (2020)
	Georgia: 0.7	
	Twigs: 0.29	Fidan et al. (2019)
	Leaves: 0.32	
	Tunisia: 0.22	Jemâa et al. (2012)
	Algeria: 0.44	
	Morocco: 0.33	
	0.7	Caputo et al. (2017)
	SFME: 0.4	Bendjersi et al. (2016)
	HD: 0.2	
	0.55	Ivanović (2010)
	Serbian: 0.14	Riabov et al. (2020)
	0.4	Tabanca et al. (2013)
	0.44	Boulila et al. (2015)
	SDE: 0.44	Diaz-Maroto et al. (2002)
	Old: 0.3	Kilic et al. (2004)
	Young: 0.3	
α-Tocopherol	13.39	Pacifico et al. (2013)
α-Ylangene	Serbian: 0.02	Riabov et al. (2020)
	Young: 0.2	Kilic et al. (2004)
β-Pinene	2.43	Cherrat et al. (2014)
β-Cadinene	Serbian: 0.02	Riabov et al. (2020)

Table 2 continued

Compounds	Quantity (%)	References
β-Caryophyllene	Greece: 0.4	Stefanova et al. (2020)
	Georgia: 0.4	
	Fruits: 0.51	Fidan et al. (2019)
	Twigs: 0.35	
	Leaves: 0.32	
	Tunisia: 0.27	Jemâa et al. (2012)
	0.43	Ivanović (2010)
	0.4	Evrendilek (2015)
	Algeria: 0.09	Jemâa et al. (2012)
	2.1	Peixoto et al. (2017)
	0.6	Belasli et al. (2020)
	1,41	Boulila et al. (2015)
	Old: 0.3	Kilic et al. (2004)
	Young: 0.8	
β-Cubebene	Young: 0.1	Kilic et al. (2004)
β-Cyclogermacrane	1.11	Nafis et al. (2020)
β-Elemene	Georgia: 0.1	Stefanova et al. (2020)
	Fruits: 7.45	Fidan et al. (2019)
	Twigs: 0.25	
	Leaves: 0.78	
	Tunisia: 0.08	Jemâa et al. (2012)
	Algeria: 0.31	
	Morocco: 0.16	
	Tunisia: 0.17	Jemâa et al. (2012)
	0.4	Caputo et al. (2017)
	SFME: 0.3	Bendjersi et al. (2016)
	HD: 0.1	
	Old: 0.1	Kilic et al. (2004)
	Young: 0.1	
	0.3	Belasli et al. (2020)
	Old: 1.4	Kilic et al. (2004)
	Young: 1.8	
β-Eudesmol	Georgia: 0.7	Stefanova et al. (2020)
	Fruits: 0.37	Fidan et al. (2019)
	Twigs: 0.32	
	Leaves: 0.47	
	SFME: 0.2	Bendjersi et al. (2016)
	HD: 0.4	
	0.3	Tabanca et al. (2013)
	SDE: 0.37	Diaz-Maroto et al. (2002)
	SPME: 0.29	
	1.27	Pacifico et al. (2013)
β-Funebrene	0.5	Caputo et al. (2017)
β-Guaiene	Serbian: 0.06	Riabov et al. (2020)
β-Gurjunene	Tunisia: 0.23	Jemâa et al. (2012)
β-Isoprpyl	Tunisia: 0.05	Jemâa et al. (2012)
β-Linalool	Fruits: 2.16	Fidan et al. (2019)
	Twigs: 3.80	
	Leaves: 4.92	
β-Maaliene	Morocco: 0.04	Jemâa et al. (2012)

Table 2 continued

Compounds	Quantity (%)	References
β-Myrcene	Greece: 0.5	Stefanova et al. (2020)
	Georgia: 1.3	
	Fruits: 0.34	Fidan et al. (2019)
	Twigs: 0.19	
	Leaves: 0.31	
	Tunisia: 0.30	Jemâa et al. (2012)
	Algeria: 0.87	
	Morocco: 0.80	
	SFME: 1.8	Bendjersi et al. (2016)
	HD: 0.7	
	0.14	Ivanović (2010)
	16.6	Peixoto et al. (2017)
	Serbian: 0.45	Riabov et al. (2020)
	Russian: 0.05	
β-Myrcene	0.39	Boulila et al. (2015)
β-Ocimene	Tunisia: 0.04	Jemâa et al. (2012)
	Algeria: 0.28	
	0.2	Peixoto et al. (2017)
β-Phellandrene	Tunisia: 3.85	Jemâa et al. (2012)
	Algeria: 5.71	
	Serbian: 6.87	Riabov et al. (2020)
	Russian: 0.07	
β-Pinene	Greece: 3.6	Stefanova et al. (2020)
	Georgia: 3.7	
	Fruits: 0.28	Fidan et al. (2019)
	Twigs: 3.44	
	Leaves: 2.45	
	Tunisia: 1.39	Jemâa et al. (2012)
	Algeria: 1.95	
	Morocco: 1.92	
	1.4	Caputo et al. (2017)
	SFME: 2.3	Bendjersi et al. (2016)
	HD: 3.8	
	3.52	Ivanović (2010)
	Serbian: 3.31	Riabov et al. (2020)
	Russian: 6.12	
	3.6	Tabanca et al. (2013)
	3.2	Belasli et al. (2020)
	7.12	Boulila et al. (2015)
	SDE: 3.47	Diaz-Maroto et al. (2002)
	Old: 3.0	Kilic et al. (2004)
	Young: 3.8	
β-Pinene Oxide	0.1	Caputo et al. (2017)
β-Selinene	Algeria: 0.04	Jemâa et al. (2012)
	Morocco: 0.18	
	Cultivated: 0.473	Conforti et al. (2006)
	HD: 0.2	Bendjersi et al. (2016)
	Serbian: 0.08	Riabov et al. (2020)
	Old: 0.1	Kilic et al. (2004)
	Young: 0.1	

Table 2 continued

Compounds	Quantity (%)	References
γ-Cadinene	Old: 0.1	Kilic et al. (2004)
	Young: 0.3	
β-Sitosterol	1.77	Pacifico et al. (2013)
β-Terpinene	Serbian: 0.18	Riabov et al. (2020)
	Russian: 0.10	
γ-Elemene	1.0	Cherrat et al. (2014)
γ-Guryunene	0.36	Cherrat et al. (2014)
γ-Cadinene	Algeria: 0.07	Jemâa et al. (2012)
	SFME: 0.1	Bendjersi et al. (2016)
	HD: 0.2	
γ-Gurjunene	Wild: 2.524	Conforti et al. (2006)
γ-Himachalene	0.1	Caputo et al. (2017)
γ-Muurolene	0.2	Peixoto et al. (2017)
	Serbian: 0.01	Riabov et al. (2020)
γ-Phenylpropyl Acetate	Algeria: 0.09	Jemâa et al. (2012)
γ-Terpinene	Greece: 3.3	Stefanova et al. (2020)
	Georgia: 29.2	
	Fruits: 0.44	Fidan et al. (2019)
	Twigs: 1.35	
	Leaves: 0.99	
	Tunisia: 0.26	Jemâa et al. (2012)
	Algeria: 0.22	
	Morocco: 0.62	
	1.24	Nafis et al. (2020)
	1.0	Caputo et al. (2017)
	SFME: 0.5	Bendjersi et al. (2016)
	HD: 0.5	
	0.74	Ivanović (2010)
	Serbian: 0.45	Riabov et al. (2020)
	Russian: 0.44	
	0.3	Tabanca et al. (2013)
	1.0	Evrendilek (2015)
	0.9	Belasli et al. (2020)
	0,61	Boulila et al. (2015)
	SDE: 0.46	Diaz-Maroto et al. (2002)
	0.27	
	Old: 0.2	Kilic et al. (2004)
	Young: 0.1	
δ-2-Carene	0.4	Caputo et al. (2017)
δ-3-Carene	Tunisia: 0.11	Jemâa et al. (2012)
	Algeria: 0.42	
	Morocco: 0.19	
	0.24	Ivanović (2010)
	SFME: 1.8	Bendjersi et al. (2016)
	HD: 0.8	
	Young: 0.2	Kilic et al. (2004)
	0.6	Belasli et al. (2020)
δ-4-Carene	Wild: 2.398	Conforti et al. (2006)
δ-Amorphene	0.1	Caputo et al. (2017)

Table 2 continued

Compounds	Quantity (%)	References
δ-Cadinene	Tunisia: 0.10	Jemâa et al. (2012)
	Algeria: 0.09	
	Cultivated: 0.659	Conforti et al. (2006)
	0.2	Caputo et al. (2017)
	SFME: 0.2	Bendjersi et al. (2016)
	HD: 0.2	
	0.27	Ivanović (2010)
	0.6	Peixoto et al. (2017)
	Serbian: 0.34	Riabov et al. (2020)
	Old: 0.1	Kilic et al. (2004)
	Young: 0.3	
	0.2	Belasli et al. (2020)
	0,46	Boulila et al. (2015)
δ-Elemene	0.14	Cherrat et al. (2014)
	Serbian: 0.01	Riabov et al. (2020)
δ-Gurjunene	Tunisia: 0.09	Jemâa et al. (2012)
δ-Selinene	Serbian: 0.01	Riabov et al. (2020)
δ-Terpineol	SFME: 0.7	Bendjersi et al. (2016)
	HD: 0.5	
	0.57	Ivanović (2010)
	0.9	Tabanca et al. (2013)
	0.2	Belasli et al. (2020)
δ-Terpinyl Acetate	0.68	Ivanović (2010)
	Old: 0.4	Kilic et al. (2004)
	Young: 0.2	
ρ-Mentha-3,8-Diene	0.5	Caputo et al. (2017)
τ-Cadinol	Fruits: 0.44	Fidan et al. (2019)
	Twigs: 0.38	
	Leaves: 0.55	
τ -Muurolol	0.7	Belasli et al. (2020)
	0.11	Boulila et al. (2015)

HD Hydrodistillation, *Old* leaves taken from the lower part of the plant, *SDE* Simultaneous distillation Extraction, *SFME* Solvent Free Microwave Extraction, *SPME* Solid Phase MicroExtraction, *Young* leaves taken from the upper part of the plant

2000; Yoshikawa et al. 2000; Hibasami et al. 2003; De Marino et al. 2004; Komiya et al. 2004; Fang et al. 2005; Chen et al. 2014). The most found sesquiterpenes in non-polar fraction were Costunolide, β-Caryophyllene (0.09–2.1%), Caryophyllene oxide (0.1–1.8%), and β-Elemene (0.1–7.45%) (Table 2). Sesquiterpene lactones are a class of sesquiterpenoids known for their pharmacological properties due to their structure. Many studies demonstrated that the α-methylene-γ-lactone group is the one linked to the biological activities of these molecules (Barla et al. 2007; Ghantous et al. 2010; Lin et al. 2015). Costunolide and dehydrocostuslactone, are two common sesquiterpene lactones with demonstrated beneficial activities including inhibition of cancer cells proliferation, anti-angiogenic activity, induction of cancer cell differentiation, anti-tumor activity (Lin et al. 2015). Luna-Herrera et al. (2007) identified and purified the same two sesquiterpene lactones, costunolide and dehydrocostuslactone, to test them individually, and found out that their antimicrobial synergistic effect was stronger than the single effects exerted by each molecule. Turk et al. (2019) isolated 21 different molecules belonging to sesquiterpene lactones class, including reynosin, santamarine, costunolide, dehydrocostus lactone, zaluzanin C and D,

Table 3 Main organic compounds isolated from *L. nobilis* extract

Compounds	Plant organ	Quantity	Method	References
(1′S,6′R)-8′-Hydroxyabscisic Acid O-β-D-Glucoside	Leaves	10.2 mg/2.5 kg dried leaves	^{1}H-NMR, ^{13}C-NMR, HR-QTOF-MS	Duc Dat et al. (2019)
(6S,9R)-Roseoside	Leaves	9.5 mg/2.5 kg dried leaves	^{1}H-NMR, ^{13}C-NMR, HR-QTOF-MS	Duc Dat et al. (2019)
(6S,9R)-Vomifoliol-9-O-β-D-Apiofuranosyl-(1′′ → 6′)-O-β-D-Glucopyranoside	Leaves	8.5 mg/2.5 kg dried leaves	^{1}H-NMR, ^{13}C-NMR, HR-QTOF-MS	Duc Dat et al. (2019)
1-Epi-tatridin B	Leaves	0.7 mg/1.5 kg	^{1}H-NMR, ^{13}C-NMR, HR-ESI–MS	Turk et al. (2019)
11-Exo-methylenesantonin	Leaves	8.8 mg/1.5 kg	^{1}H-NMR, ^{13}C-NMR, HR-ESI–MS	Turk et al. (2019)
11,13-dehydrosantonin	Leaves	3.5 mg/100 g	^{1}H-NMR, ^{13}C-NMR, EI-MS	Barla et al. (2007)
	Leaves	113.8 mg/1.5 kg	HPLC, ^{1}H-NMR, ^{13}C-NMR	Julianti et al. (2012)
15-Acetoxycostunolide	Leaves	23.9 mg/6 kg of dried leaves	IR, ESI–MS, HR-ESI–MS, 1D-2D NMR	Chen et al. (2014)
1β-Hydroxyarbusculin A	Leaves	41.6 mg/6 kg of dried leaves	IR, ESI–MS, HR-ESI–MS, 1D-2D NMR	Chen et al. (2014)
1β,2β-dihydroxy-5α,6β, 7αH-eudesma-4(15),11(13)-dien-12,6-olide	Leaves	5.5 mg/1.5 kg	HPLC, ^{1}H-NMR, ^{13}C-NMR	Julianti et al. (2012)
2-Hydroxy benzoic acid	Fruits	Var. Greece: Free: 137.9 ± 0.90 μg/g Conjugated: 84.0 ± 0.81 μg/g Var. Georgia: Free: 33.6 ± 0.30 μg/g Conjugated: 68.5 ± 0.70 μg/g	HPLC	Petkova et al. (2019)
2-(4-hydroxy-3-methoxyphenyl)-ethyl-O-β-D-glucopyranoside	Leaves	1.3 mg/404 g of fresh leaves	HPLC, ^{1}H-NMR, ^{13}C-NMR	De Marino et al. (2004)
2′′-Rhamnosylisovitexin	Leaves	13.4 mg/25 g	^{1}H-NMR, ^{13}C-NMR, HPLC	Dall'Acqua et al. (2009)
3-Oxoeudesma-1,4,11(13)-Trien-12,6α-Olide	Leaves	0.009%	HPLC, ^{1}H-NMR, ^{13}C-NMR	Yoshikawa et al. (2000)
3-Oxoeudesma-L,4(15),Ll(13)Triene-12,6α-Olide	Leaves	2.6 mg/50 g of dried leaves	^{1}H-NMR, ^{13}C-NMR	Komiya et al. (2004)
3'-Methoxyquercetin-3-O-[6-O-(rhamnopyranosyl) glucopyranoside]	Leaves	12.2 mg/25 g	^{1}H-NMR, ^{13}C-NMR, HPLC	Dall'Acqua et al. (2009)
3α-Acetoxyeudesma-1,4(15),11(13)-Trien-12,6α-Olide	Leaves	18.9 mg/6 kg of dried leaves	IR, ESI–MS, HR-ESI–MS, 1D-2D NMR	Chen et al. (2014)
3α-Peroxyarmefolin	Leaves	6.2 mg/1.5 kg	^{1}H-NMR, ^{13}C-NMR, HR-ESI–MS	Turk et al. (2019)
	Leaves	46.3 mg/1.5 kg	HPLC, ^{1}H-NMR, ^{13}C-NMR	Julianti et al. (2012)
3β -Chlorodehydrocostuslactone	Leaves	4.6 mg/350 g	^{1}H-NMR, ^{13}C-NMR, HPLC	Dall'Acqua et al. (2006)

Table 3 continued

Compounds	Plant organ	Quantity	Method	References
3,4-Dihydroxy benzoic acid	Fruits	Var. Greece: Free: 10.0 ± 0.09 µg/g Conjugated: 224.3 ± 2.20 µg/g Var. Georgia: Free: 8.9 ± 0.89 µg/g Conjugated: 35.7 ± 0.31 µg/g	HPLC	Petkova et al. (2019)
3α-Acetoxyeudesma-1,4(15),11(13)-Trien-12,6α-Olide	Leaves	0.004%	HPLC, ^{1}H-NMR, ^{13}C-NMR	Yoshikawa et al. (2000)
4,5-Dihydroblumenol A	Leaves	5.3 mg/404 g of fresh leaves	HPLC, ^{1}H-NMR, ^{13}C-NMR	De Marino et al. (2004)
4α-hydroxy-guaia-10(14),11(13)-diene-12,6α-olide	Leaves	2.2 mg/1.5 kg	^{1}H-NMR, ^{13}C-NMR, HR-ESI–MS	Turk et al. (2019)
5α,9-Dimethyl-3-methylene-3,3 α,4,5,5α,6,7,8-octahydro-1-oxacyclopenta[c]azulen-2-one	Leaves	4.8 mg/350 g	^{1}H-NMR, ^{13}C-NMR, HPLC	Dall'Acqua et al. (2006)
Alangioside A	Leaves	2.2 mg/404 g of fresh leaves	HPLC, ^{1}H-NMR, ^{13}C-NMR	De Marino et al. (2004)
Alangioside B	Leaves	–	^{1}H-NMR, ^{13}C-NMR, HR-QTOF-MS	L. Duc Dat et al. (2019)
Altissin	Leaves	3.1 mg/1.5 kg	^{1}H-NMR, ^{13}C-NMR, HR-ESI–MS	Turk et al. (2019)
Anhydroperoxycostunolide	Leaves	1.2 mg/50 g of dried leaves	^{1}H-NMR, ^{13}C-NMR	Komiya et al. (2004)
	Leaves	30.9 mg/1.5 kg	HPLC, ^{1}H-NMR, ^{13}C-NMR	Julianti et al. (2012)
Apigenin	Leaves	Var. Greece Free: 268.6 µg/g dw Conjugated: 1433.6 µg/g dw Var. Georgia Free: 161.7 µg/g dw Conjugated: 262.7 µg/g dw	HPLC	Stefanova et al. (2020)
	Fruits	Var. Georgia: Free: 67.8 ± 0.71 µg/g Conjugated: 66.8 ± 0.65 µg/g	HPLC	Petkova et al. (2019)
Armefolin	Leaves	–	^{1}H-NMR, ^{13}C-NMR, HR-ESI–MS	Turk et al. (2019)

Table 3 continued

Compounds	Plant organ	Quantity	Method	References
Artemorin	Leaves	24.0 mg/350 g	^{1}H-NMR, ^{13}C-NMR, HPLC	Dall'Acqua et al. (2006)
	Leaves	505 mg/2180 g	^{1}H-NMR, ^{13}C-NMR	El-Feraly and Benigni (1980)
Baynol C	Leaves	59.6 mg/1.5 kg	HPLC, ^{1}H-NMR, ^{13}C-NMR	Julianti et al. (2012)
Benzyl alcohol xylopyranosyl (1–6) glucopyranoside	Leaves	1.5 mg/404 g of fresh leaves	HPLC, ^{1}H-NMR, ^{13}C-NMR	De Marino et al. (2004)
Blumenol C	Leaves	0.8 mg/404 g of fresh leaves	HPLC	De Marino et al. (2005)
Caffeic acid	Leaves	Var. Greece Free: 586.1 µg/g dw Conjugated: 56.8 µg/g dw Var. Georgia Free: 31.4 µg/g dw Conjugated: 789.3 µg/g dw	HPLC	Stefanova et al. (2020)
	Fruits	Var. Greece: Conjugated: 108.5 ± 1.00 µg/g Var. Georgia: Free: 65.0 ± 0.55 µg/g Conjugated: 439.2 ± 4.13 µg/g	HPLC	Petkova et al. (2019)
Caryophyllene oxide	Leaves	0.0008%	HPLC, ^{1}H-NMR, ^{13}C-NMR	Yoshikawa et al. (2000)
Catechin	Leaves	22.9 mg/25 g	^{1}H-NMR, ^{13}C-NMR, HPLC	Dall'Acqua et al. (2009)
Chlorogenic acid	Leaves	Var. Greece Free: 243.9 µg/g dw Var. Georgia Conjugated: 56.8 µg/g dw	HPLC	Stefanova et al. (2020)
	Fruits	Var. Greece: Free: 61.8 ± 0.59 µg/g Conjugated: 106.7 ± 1.01 µg/g Var. Georgia: Conjugated: 32.8 ± 0.33 µg/g	HPLC	Petkova et al. (2019)

Table 3 continued

Compounds	Plant organ	Quantity	Method	References
Cinnamic Acid	Leaves	Var. Greece Free: 135.0 μg/g dw Conjugated: 486.2 μg/g dw Var. Georgia Free: 22.7 μg/g dw Conjugated: 513.4 μg/g dw	HPLC	Stefanova et al. (2020)
	Fruits	Var. Greece: Free: 66.9 ± 0.66 μg/g Conjugated: 174.9 ± 1.68 μg/g Var. Georgia: Free: 73.9 ± 0.69 μg/g Conjugated: 36.4 ± 0.30 μg/g	HPLC	Petkova et al. (2019)
Cinnamtannin B-1	Leaves	2.3 mg/25 g	^{1}H-NMR, ^{13}C-NMR, HPLC	Dall'Acqua et al. (2009)
Citroside A	Leaves	1.5 mg/404 g of fresh leaves	HPLC, ^{1}H-NMR, ^{13}C-NMR	De Marino et al. (2004)
Costunolide	Leaves	1.17 g/404 g of fresh leaves	HPLC	De Marino et al. (2005)
	Leaves	12 mg/21 g of dried leaves	^{1}H-NMR ^{13}C-NMR	Hibasami et al. (2003)
	Leaves	0.18%	HPLC	Matsuda et al. (2000)
	Leaves	0.18%	HPLC, ^{1}H-NMR, ^{13}C-NMR	Yoshikawa et al. (2000)
	Leaves	15 mg/100 g	^{1}H-NMR, ^{13}C-NMR, EI-MS	Barla et al. (2007)
	Leaves	13.4 mg/350 g	^{1}H-NMR, ^{13}C-NMR, HPLC	Dall'Acqua et al. (2006)
	Leaves	964 mg/2180 g	^{1}H-NMR, ^{13}C-NMR	El-Feraly and Benigni (1980)
	Leaves	–	^{1}H-NMR, ^{13}C-NMR	Luna-Herrera (2007)
	Leaves	3.0 mg/1.5 kg	^{1}H-NMR, ^{13}C-NMR, HR-ESI–MS	Turk et al. (2019)
Dehydrocostus lactone	Leaves	0.080%	HPLC	Matsuda et al. (2000)
	Leaves	0.008%	HPLC, ^{1}H-NMR, ^{13}C-NMR	Yoshikawa et al. (2000)
	Leaves	24.4 mg/350 g	^{1}H-NMR, ^{13}C-NMR, HPLC	Dall'Acqua et al. (2006)
	Leaves	–	^{1}H-NMR, ^{13}C-NMR	Luna-Herrera (2007)
	Leaves	14.5 mg/1.5 kg	^{1}H-NMR, ^{13}C-NMR, HR-ESI–MS	Turk et al. (2019)

Table 3 continued

Compounds	Plant organ	Quantity	Method	References
Dendranthemoside A	Leaves	1.8 mg/404 g of fresh leaves	HPLC, ^{1}H-NMR, ^{13}C-NMR	De Marino et al. (2004)
Desacetyllaurenobiolide	Leaves	–	^{1}H-NMR, ^{13}C-NMR	El-Feraly and Benigni (1980)
D-Glucol-Glycero-3-Octulose	Leaves	2 g/160 g of fresh leaves 37.29 ± 1.19% of total extract	^{1}H-NMR, ^{13}C-NMR GC–MS, ^{1}H and 2D NMR	Sakata et al. (1989), de Falco et al. (2018)
Entgermacra-4(15),5,10(14)-Trien-1α-Ol	Leaves	8.1 mg/6 kg of dried leaves	IR, ESI–MS, HR-ESI–MS, 1D-2D NMR	Chen et al. (2014)
Eremanthine	Leaves	10.3 mg/1.5 kg	^{1}H-NMR, ^{13}C-NMR, HR-ESI–MS	Turk et al. (2019)
Etemanthine	Leaves	0.0041%	HPLC	Matsuda et al. (2000)
Ferulic acid	Leaves	Var. Greece Free: 300.1 µg/g dw Conjugated: 2193.0 µg/g dw Var. Georgia Free: 29.4 µg/g dw Conjugated: 70.4 µg/g dw	HPLC	Stefanova et al. (2020)
	Fruits	Var. Greece: Free: 159.0 ± 1.11 µg/g Conjugated: 171.2 ± 1.65 µg/g Var. Georgia: Free: 59.1 ± 0.51 µg/g Conjugated: 144.0 ± 1.30 µg/g	HPLC	Petkova et al. (2019)
Gallic acid	Leaves	Var. Greece Free: 24.8 µg/g dw	HPLC	Stefanova et al. (2020)
	Fruits	Greece: Free: 10.2 ± 0.09 µg/g Georgia: Conjugated: 27.0 ± 0.25 µg/g	HPLC	Petkova et al. (2019)
Gallicin	Leaves	–	^{1}H-NMR, ^{13}C-NMR	El-Feraly and Benigni (1980)
Gazaniolide	Leaves	14 mg/100 g	^{1}H-NMR, ^{13}C-NMR, EI-MS	Barla et al. (2007)
Germacra-4(15),5,10(14)-Trien-Lβ-Ol	Leaves	0.00049%	HPLC	Matsuda et al. (2000)

Table 3 continued

Compounds	Plant organ	Quantity	Method	References
Germacranolide	Leaves	1.5 mg/1.5 kg	^{1}H-NMR, ^{13}C-NMR, HR-ESI–MS	Turk et al. (2019)
Hesperetin	Leaves	Var. Greece	HPLC	Stefanova et al. (2020)
		Conjugated: 116.4 μg/g dw		
		Var. Georgia		
		Conjugated: 31.2 μg/g dw		
	Fruits	Var. Greece:	HPLC	Petkova et al. (2019)
		Conjugated: 38.5 ± 0.37 μg/g		
Hydroperoxide-magnolialide	Leaves	21.7 mg/1.5 kg	HPLC, ^{1}H-NMR, ^{13}C-NMR	Julianti et al. (2012)
Hyperoside	Leaves	Var. Greece	HPLC	Stefanova et al. (2020)
		Free: 141.8 μg/g dw		
Icariside B1	Leaves	1.4 mg/404 g of fresh leaves	HPLC, ^{1}H-NMR, ^{13}C-NMR	De Marino et al. (2004)
Kaempferol	Leaves	Var. Greece	HPLC	Stefanova et al. (2020)
		Free: 122.2 μg/g dw		
		Conjugated: 1981.3 μg/g dw		
		Var. Georgia		
		Free: 250.7 μg/g dw		
		Conjugated: 688.1 μg/g dw		
	Petals	1.9 mg/240 g	HPLC	Shimada et al. (2020)
	Fruits	Var. Greece:	HPLC	Petkova et al. (2019)
		Free: 13.5 ± 0.12 μg/g		
		Conjugated: 35.5 ± 0.30 μg/g		
		Var. Georgia:		
		Free: 33.5 ± 0.34 μg/g		
		Conjugated: 44.9 ± 0.43 μg/g		
Kaempferol-3-O-(2″,4″-di-E-p-coumaroyl)-rhamnoside	Leaves	22.9 mg/25 g	^{1}H-NMR, ^{13}C-NMR, HPLC	Dall'Acqua et al. (2009)
Kaempferol-3-O-[6-O-(rhamnopyranosyl) glucopyranoside]	Leaves	2.8 mg/25 g	^{1}H-NMR, ^{13}C-NMR, HPLC	Dall'Acqua et al. (2009)

Table 3 continued

Compounds	Plant organ	Quantity	Method	References
Kaempferol-3-O-Arabinofuranoside	Petals	9.8 mg/240 g	HPLC	Shimada et al. (2020)
Kaempferol-3-O-glucopyranoside	Leaves	23.0 mg/25 g	^{1}H-NMR, ^{13}C-NMR, HPLC	Dall'Acqua et al. (2009)
Kaempferol-3-O-R-L-(2^{II}-E-P-Coumaroyl) Rhamnoside	Leaves	0.9 mg/404 g of fresh leaves	HPLC, ^{1}H-NMR, ^{13}C-NMR	De Marino et al. (2004)
Kaempferol-3-O-R-L-(3^{II},4^{II}-di-E-P-Coumaroyl) Rhamnoside	Leaves	1.1 mg/404 g of fresh leaves	HPLC, ^{1}H-NMR, ^{13}C-NMR	De Marino et al. (2004)
Kaempferol-3-O-rhamnopyranoside	Leaves	28.0 mg/25 g	^{1}H-NMR, ^{13}C-NMR, HPLC	Dall'Acqua et al. (2009)
Kaempferol-3-Oarabinopyranoside	Leaves	16.0 mg/25 g	^{1}H-NMR, ^{13}C-NMR, HPLC	Dall'Acqua et al. (2009)
Laurenoperoxylide A	Leaves	1.5 mg/1.5 kg	^{1}H-NMR, ^{13}C-NMR, HR-ESI–MS	Turk et al. (2019)
Laurenoperoxylide B	Leaves	2.4 mg/1.5 kg	^{1}H-NMR, ^{13}C-NMR, HR-ESI–MS	Turk et al. (2019)
Lauroside A	Leaves	2.5 mg/404 g of fresh leaves	HPLC, ^{1}H-NMR, ^{13}C-NMR	De Marino et al. (2004)
Lauroside B	Leaves	1.5 mg/404 g of fresh leaves	HPLC, ^{1}H-NMR, ^{13}C-NMR	De Marino et al. (2004)
	Leaves	1.5 mg/404 g of fresh leaves	HPLC, ^{1}H-NMR, ^{13}C-NMR	Panza et al.(2011)
Lauroside C	Leaves	0.9 mg/404 g of fresh leaves	HPLC, ^{1}H-NMR, ^{13}C-NMR	De Marino et al. (2004)
Lauroside D	Leaves	1.4 mg/404 g of fresh leaves	HPLC, ^{1}H-NMR, ^{13}C-NMR	De Marino et al. (2004)
Lauroside E	Leaves	1.8 mg/404 g of fresh leaves	HPLC, ^{1}H-NMR, ^{13}C-NMR	De Marino et al. (2004)
Lauroxepine	Leaves	3.5 mg/100 g	^{1}H-NMR, ^{13}C-NMR, EI-MS	Barla et al. (2007)
Laurupene A	Leaves	11.4 mg/6 kg of dried leaves	IR, ESI–MS, HR-ESI–MS, 1D-2D NMR	Chen et al. (2014)
Laurupene B	Leaves	4.0 mg/6 kg of dried leaves	IR, ESI–MS, HR-ESI–MS, 1D-2D NMR	Chen et al. (2014)
Lauruside E	Leaves	7.2 mg/2.5 kg dried leaves	^{1}H-NMR, ^{13}C-NMR, HR-QTOF-MS	L. Duc Dat et al. (2019)
Lauruside F	Leaves	6.5 mg/2.5 kg dried leaves	^{1}H-NMR, ^{13}C-NMR, HR-QTOF-MS	L. Duc Dat et al. (2019)
Lauruside G	Leaves	9.0 mg/2.5 kg dried leaves	^{1}H-NMR, ^{13}C-NMR, HR-QTOF-MS	L. Duc Dat et al. (2019)
Lucentolide	Leaves	247.0 mg/1.5 kg	HPLC, ^{1}H-NMR, ^{13}C-NMR	Julianti et al. (2012)

Table 3 continued

Compounds	Plant organ	Quantity	Method	References
Luteolin	Leaves	Var. Greece Free: 4.8 μg/g dw Conjugated: 388.6 μg/g dw Var. Georgia Free: 59.0 μg/g dw Conjugated: 839.1 μg/g dw	HPLC	Stefanova et al. (2020)
	Fruits	Var. Greece: Free: 3.9 ± 0.01 μg/g Conjugated: 32.3 ± 0.31 μg/g Var. Georgia: Free: 59.0 ± 0.63 μg/g Conjugated: 20.1 ± 0.20 μg/g	HPLC	Petkova et al. (2019)
Lyoniside	Leaves	0.9 mg/404 g of fresh leaves	HPLC, ^{1}H-NMR, ^{13}C-NMR	De Marino et al. (2004)
Magnolialide	Leaves	0.0066%	HPLC	Matsuda et al. (2000)
	Leaves	5.1 mg/1.5 kg	^{1}H-NMR, ^{13}C-NMR, HR-ESI–MS	Turk et al. (2019)
	Leaves	11.5 mg/1.5 kg	HPLC, ^{1}H-NMR, ^{13}C-NMR	Julianti et al. (2012)
Maroniolid	Leaves	4.2 mg/1.5 kg	^{1}H-NMR, ^{13}C-NMR, HR-ESI–MS	Turk et al. (2019)
Methyl Gallate	Petals	18.3 mg/240 g	HPLC	Shimada et al. (2020)
Methyl-1β,2β,6α-trihydroxy-5α,7αH-eudesma-4(15),11,(13)-dien-12-oate	Leaves	3.8 mg/1.5 kg	HPLC, ^{1}H-NMR, ^{13}C-NMR	Julianti et al. (2012)
Multinoside A Acetate	Petals	4.0 mg/240 g	HPLC	Shimada et al. (2020)
Myricetin	Leaves	Var. Greece Free: 124.5 μg/g dw Conjugated: 75.2 μg/g dw Var. Georgia Free: 75.5 μg/g dw Conjugated: 47.2 μg/g dw	HPLC	Stefanova et al. (2020)
	Fruits	Var. Greece: Free: 43.2 ± 0.39 μg/g Conjugated: 40.3 ± 0.40 μg/g Var. Georgia: Conjugated: 41.6 ± 0.37 μg/g	HPLC	Petkova et al. (2019)

Table 3 continued

Compounds	Plant organ	Quantity	Method	References
Oplopanone	Leaves	0.0011% from the leaves	HPLC	Matsuda et al. (2000)
Protocatechuic acid	Leaves	Var. Greece	HPLC	Stefanova et al. (2020)
		Conjugated: 17.2 μg/g dw		
		Var. Georgia		
		Free: 13.3 μg/g dw		
		Conjugated: 68.6 μg/g dw		
Quercetin	Leaves	Var. Greece	HPLC	Stefanova et al. (2020)
		Free: 48.9 μg/g dw		
		Conjugated: 42.3 μg/g dw		
		Var. Georgia		
		Free: 65.3 μg/g dw		
		Conjugated: 44.9 μg/g dw		
	Petals	6.3 mg/240 g	HPLC	Shimada et al. (2020)
	Fruits	Var. Greece:	HPLC	Petkova et al. (2019)
		Free: 24.0 ± 0.20 μg/g		
		Conjugated: 32.7 ± 0.31 μg/g		
		Var. Georgia:		
		Free: 21.4 ± 0.21 μg/g		
		Conjugated: 22.8 ± 0.20 μg/g		
Quercetin-3-O-[6-O-(rhamnopyranosyl) glucopyranoside]	Leaves	15.5 mg/25 g	^{1}H-NMR, ^{13}C-NMR, HPLC	Dall'Acqua et al. (2009)
Quercetin-3-O-glucopyranoside	Leaves	38.0 mg/25 g	^{1}H-NMR, ^{13}C-NMR, HPLC	Dall'Acqua et al. (2009)
Quercetin-3-O-rhamnopyranoside	Leaves	21.0 mg/25 g	^{1}H-NMR, ^{13}C-NMR, HPLC	Dall'Acqua et al. (2009)
Reynosin	Leaves	2.5 mg/404 g of leaves	HPLC	De Marino et al. (2005)
	Leaves	64.2 mg/6 kg of dried leaves	IR, ESI–MS HR-ESI–MS, 1D-2D NMR	Chen et al. (2014)
	Leaves	0.018%	HPLC, 1H-NMR, 13C-NMR	Yoshikawa et al. (2000)
	Leaves	4 mg/100 g	^{1}H-NMR, ^{13}C-NMR, EI-MS	Barla et al. (2007)
	Leaves	195 mg/2180 g	^{1}H-NMR, ^{13}C-NMR	El-Feraly and Benigni (1980)
	Leaves	10.2 mg/1.5 kg	^{1}H-NMR, ^{13}C-NMR, HR-ESI–MS	Turk et al. (2019)
	Leaves	172.8 mg/1.5 kg	HPLC, ^{1}H-NMR, ^{13}C-NMR	Julianti et al. (2012)

Table 3 continued

Compounds	Plant organ	Quantity	Method	References
Rosmarinic acid	Leaves	Var. Greece Free: 47.5 μg/g dw	HPLC	Stefanova et al. (2020)
	Fruits	Var. Greece: Free: 0.5 ± 0.00 μg/g Conjugated: 25.6 ± 0.18 μg/g	HPLC	Petkova et al. (2019)
Rutin	Leaves	Var. Greece Free: 217.4 μg/g dw	HPLC	Stefanova et al. (2020)
	Fruits	Var. Greece: Free: 24.3 ± 0.22 μg/g Var. Georgia: Free: 65.5 ± 0.68 μg/g	HPLC	Petkova et al. (2019)
Salicylic acid	Leaves	Var. Greece Free: 207.3 μg/g dw Conjugated: 41.7 μg/g dw Var. Georgia Conjugated: 29.4 μg/g dw	HPLC	Stefanova et al. (2020)
Santamarine	Leaves	1.0 mg/404 g of fresh leaves	HPLC	De Marino et al. (2005)
	Leaves	32.2 mg/6 kg of dried leaves	IR, ESI–MS, HR-ESI–MS, 1D-2D NMR	Chen et al. (2014)
	Leaves	0.041%	HPLC	Matsuda et al. (2000)
	Leaves	0.041%	HPLC, ^{1}H-NMR, ^{13}C-NMR	Yoshikawa et al. (2000)
	Leaves	3 mg/100 g	^{1}H-NMR, ^{13}C-NMR, EI-MS	Barla et al. (2007)
	Leaves	96 mg/2180 g	^{1}H-NMR, ^{13}C-NMR	El-Feraly and Benigni (1980)
	Leaves	10 mg/1.5 kg	^{1}H-NMR, ^{13}C-NMR, HR-ESI–MS	Turk et al. (2019)
	Leaves	139.4 mg/1.5 kg	HPLC, ^{1}H-NMR, ^{13}C-NMR	Julianti et al. (2012)
Sesquiterpene 1	Leaves	2.8 mg/404 g of fresh leaves	HPLC	De Marino et al. (2005)
Sesquiterpene 2	Leaves	1.1 mg/404 g of fresh leaves	HPLC	De Marino et al. (2005)

Table 3 continued

Compounds	Plant organ	Quantity	Method	References
Sinapic acid	Leaves	Var. Greece Free: 607.7 μg/g dw Conjugated: 560.4 μg/g dw Var. Georgia Conjugated: 1513.9 μg/g dw	HPLC	Stefanova et al. (2020)
	Fruits	Var. Greece: Conjugated: 460.2 ± 4.41 μg/g Var. Georgia: Free: 0.3 ± 0.00 μg/g Conjugated: 96.5 ± 0.81 μg/g	HPLC	Petkova et al. (2019)
Sivosinolide	Leaves	1.5 mg/1.5 kg	^{1}H-NMR, ^{13}C-NMR, HR-ESI–MS	Turk et al. (2019)
Spathulenol	Leaves	0.0076%	HPLC	Matsuda et al. (2000)
Spirafolide	Leaves	0.021%	HPLC	Matsuda et al. (2000)
	Leaves	2.1 mg/100 g	^{1}H-NMR, ^{13}C-NMR, EI-MS	Barla et al. (2007)
	Leaves	1.4 mg/1.5 kg	^{1}H-NMR, ^{13}C-NMR, HR-ESI–MS	Turk et al. (2019)
Syringic acid	Fruits	Var. Greece: Conjugated: 103.5 ± 1.10 μg/g Var. Georgia: Free: 65.8 ± 0.69 μg/g Conjugated: 390.7 ± 3.62 μg/g	HPLC	Petkova et al. (2019)
Tuberiferin	Leaves	4.7 mg/1.5 kg	^{1}H-NMR, ^{13}C-NMR, HR-ESI–MS	Turk et al. (2019)
	Leaves	7.9 mg/1.5 kg	HPLC, ^{1}H-NMR, ^{13}C-NMR	Julianti et al. (2012)
Vanillic acid	Fruits	Var. Greece: Free: 253.1 ± 2.40 μg/g Conjugated: 925.8 ± 9.00 μg/g Var. Georgia: Free: 105.6 ± 0.92 μg/g	HPLC	Petkova et al. (2019)

Table 3 continued

Compounds	Plant organ	Quantity	Method	References
Verlotorin	Leaves	66 mg/2180 g	^{1}H-NMR, ^{13}C-NMR	El-Feraly and Benigni (1980)
Zaluzanin C	Leaves	13.2 mg/6 kg of dried leaves	IR, ESI–MS, HR-ESI–MS, 1D-2D NMR	Chen et al. (2014)
	Leaves	0.0049%	HPLC	Matsuda et al. (2000)
	Leaves	33.9 mg/1.5 kg	^{1}H-NMR, ^{13}C-NMR, HR-ESI–MS	Turk et al. (2019)
Zaluzanin D	Leaves	5.4 mg/21 g of dried leaves	^{1}H-NMR ^{13}C-NMR	Hibasami et al. (2003)
	Leaves	35.6 mg/6 kg of dried leaves	IR, ESI–MS, HR-ESI–MS, 1D-2D NMR	Chen et al. (2014)
	Leaves	0.006%	HPLC, ^{1}H-NMR, ^{13}C-NMR	Yoshikawa et al. (2000)
	Leaves	4.8 mg/1.5 kg	^{1}H-NMR, ^{13}C-NMR, HR-ESI–MS	Turk et al. (2019)
α-Dictyopterol	Leaves	0.00055%	HPLC	Matsuda et al. (2000)
α-Eudesmol	Leaves	0.0013%	HPLC	Matsuda et al. (2000)
β-Caryophyllene	Leaves	0.0008%	HPLC, ^{1}H-NMR, ^{13}C-NMR	Yoshikawa et al. (2000)
β-Eudesmol	Leaves	0.0025%	HPLC	Matsuda et al. (2000)
	Leaves	0.0025%	HPLC, ^{1}H-NMR, ^{13}C-NMR	Yoshikawa et al. (2000)
γ-Eudesmol	Leaves	0.00095%	HPLC	Matsuda et al. (2000)
p-Coumaric acid	Leaves	Var. Greece Free: 151.1 µg/g dw Conjugated: 246.6 µg/g dw Var. Georgia Free: 45.3 µg/g dw Conjugated: 375.9 µg/g dw	HPLC	Stefanova et al. (2020)
	Fruits	Var. Greece: Free: 261.6 ± 2.34 µg/g Conjugated: 140.1 ± 1.32 µg/g Var. Georgia: Free: 9.3 ± 0.09 µg/g Conjugated: 34.9 ± 0.35 µg/g	HPLC	Petkova et al. (2019)

and other minor ones. They also found that sesquiterpene lactones from the leaves of *L. nobilis* exert their anti-inflammatory activity by inhibiting Nuclear Factor-κB (NF-κB), highlighting their importance in development of anti-inflammatory products.

Many other works have isolated well-known and unknown sesquiterpene lactones to enrich scientific literature, such as Barla et al. (2007) and Dall'Acqua et al. (2006), who demonstrated a cytotoxic activity against cancer cells, Petkova et al. (2019), who investigated the antimicrobial activity of laurel fruits.

Sesquiterpene lactones commonly found in *L. nobilis* leaves extracts were Costunolide, Santamarine, Zaluzanin D. Contrarily to essential oils, which contained non-polar sesquiterpenes, leaves extracts contained sesquiterpenes lactones, which contain several oxygen atoms. To give some examples, De Marino et al. (2004, 2005) extracted 1.17 g of Costunolide and 1 mg of Santamarine out of 404 g of dried leaves, while Hibasami et al. (2003) obtained 12 mg of Costunolide and 5.4 mg of Zaluzanin D. starting from 21 g of dried leaves (Table 3).

One of the most important secondary metabolite classes is flavonoids class, a subclass of polyphenols whose general molecular structure consists of two benzene rings and a heterocyclic ring containing one oxygen atom. They are responsible of several roles in plants such as pigmentation, signaling and regulation processes. The most efficient method to extract phenolic compounds, according to Muñiz-Márquez et al. (2013) is an extraction with a solid/liquid ratio of 1:12 (g/mL), and using sonication for 40 (min) with an ethanol concentration of 35%. However, few works among the ones we considered used an ultrasound-assisted method.

Apigenin, Hesperetin, Luteolin, Myricetin, Quercetin are the principal flavonoids found in *Laurus nobilis* leaves which were present in an order of magnitude of dozens or hundreds of micrograms every gram of dried weight. Stefanova et al. (2020) performed an extraction from laurel leaves and obtained 268.6 µg/g of Apigenin, 116.4 µg/g Hesperetin, 4.8 (Greece) and 59 (Georgia) µg/g of Luteolin, 124.5 (Greece) e 75 (Georgia) µg/g of Myricetin, 48.9 (Greece) and 65.3 (Georgia) µg/g of Quercetin (Table 3). Dall'Acqua et al. (2009) isolated ten glycosides of kaempferol and quercetin listed in Table 2 and performed *in-vitro* experiments to highlight the antioxidant properties of the extracts containing these compounds.

Megastigmanes are also important because of their aromatic properties. They are a class of molecules with 6 carbon-ring substituted on carbon 1 and 5, and with a four-carbon sidechain attached on carbon 6. The megastigmanes found in *L. nobilis* leaves extracts are different types of Laurusides (A, B, C, D, E, F, G), which consist of the general megastigmanes structure substituted with several hydroxyl groups and a glucopyranose group. These molecules are contained in few milligrams per hundreds of dried laurel leaves (De Marino et al. 2004; Panza et al. 2011; Duc Dat et al. 2019), with Lauroside A being the most abundant (2.5 mg/404 g dw).

Concerning carbohydrates, the major component in the extract was D-Gluco-L-glycero-3-octulose (37.29 ± 1.19%). The compound has been determined by classical approach by ^{1}H and ^{13}C NMR spectroscopy Sakata et al. (1989) and by metabolomics GC–MS and ^{1}H and 2D NMR methods (de Falco et al. 2018) (Table 3).

Pharmacological activity

Table 4 lists the biological activity of laurel extracts that have been studied in published articles. Several activities have been reported on essential oils and plant extracts including antibacterial, antimicrobial, antifungal, antioxidant, cytotoxic, insecticidal, nematicidal, inhibiting nitric oxide (NO) production and inhibiting microglial activation. Studies were performed on the essential oils and on the organic and aqueous extracts of the plant. Leaves were the part of the plant mostly studied and tested with different solvents used for the extraction of metabolites. In general, a certain variation of the biological activity was observed due to the geographical origin of the plant, the growing conditions, the seasonal variation, and the solvent used for metabolite extraction.

Essential oils

Bay leaf essential oils find applications for several pharmacological activities. A complete review of the observed biological activity was reported by Chahal et al. (2017) with particular interest to antibacterial,

Table 4 Biological activity of *L. nobilis* based on plant material and solvent extract

Activity	Plant organ	Extract	Method (target organism)	Tested concentration	References
Antibacterial	Leaves	Essential oil	Disk diffusion assay (*Listeria innocua, Staphylococcus aureus, Yersinia enterocolitica, Salmonella enteritidis, Salmonella typhimurium, Proteus mirabilis, Escherichia coli* O157:H7*, Klebsiella oxytoca)*	5 *µL*	Evrendilek (2015)
Antibacterial	Leaves	Essential oil	M7-A8 Method	0,05 g/100 g or 0,1 g/100 g	da Silveira et al. (2014)
Antimicrobical *Antifungal*	Leaves	Essential oil	The disc diffusion method (*Candida albicans Candida glabrata Candida krusei Candida parapsilosis, Staphylococcus aureus, Micrococcus luteus, Bacillus subtilis, Escherichia coli, Pseudomonas aeruginosa, Klebsiella pneumoniae*)	90 to 0,35 mg/mL (MIC = 2,77 e 5,55 mg/ml for yeats and 1,39 e 22,2 mg/ml for bacteria.)	Nafis et al. (2020)
Antimicrobial *Antioxidant*	Leaves	Essential oil	The disc diffusion method (*Escherichia coli, Pseudomonas aeruginosa, Bacillus cereus, Staphylococcus aureus, Saccharomyces cerevisiae, Aspergillus brasiliensis*)		Riabov et al. (2020)
			DPPH and total reduction capacity		
Antimicrobial *Antifungal* *Cytotoxyc*	Leaves	Essential oil	Halo inhibition test, MIC test (*Escherichia coli, Pseudomonas aeruginosa* and *Staphylococcus aureus)* inibition halo test (*Aspergillus niger, Aspergillus versicolor, Penicillium citrinum, Penicillium expansum*)	*E. coli* (2 µL/mL), *P. aeruginosa* and *S. aureus* (0.4 µL/mL) 1600–50 µg/mL	Caputo et al. (2017
			SH-SY5Y cell line, adenylate cyclase 1 (ADCY1), Central Nervous System		
Antibacterial *Antifungal* *Antioxidant* *Insecticidal* *Nematicidal*	Leaves, stems, flowers, barks, woods, roots, seeds, fruits	Essential oil	The disc diffusion method *(Staphylococcus aureus, Escherichia coli, Salmonella typhimurium*) *Glomus deserticola, Glomus intraradices*	125–2000 µg/ml 15 mg/L (30, 60 mg/L significant activity	Chahal et al. (2017)
			DPPH free radical scavenging and β-carotene/linoleic acid test systems	94, 65 mg/ml from 4 to 12 mg/g	
			Tribolium castaneum	1000 µl/l	
			The root-knot nematodes, Meloidogyne spp		
Antifungal	Leaves	Essential oil	Microdilution technique (*Candida albicans*); sorbitol assay; Ergosterol assay	250—500 m g/mL	Peixoto et al. (2016)
Antibacterial	Leaves	Essential oil and Supercritical CO_2 extract	Broth macrodiluition method *(Staphylococcus intermedius)*	MIC = 640 *µg/mL*	Ivanovic et al. (2010)

Table 4 continued

Activity	Plant organ	Extract	Method (target organism)	Tested concentration	References
Antioxidant *Antimicrobial*	Leaves	Essential oil	DPPH *Disc diffusion assay* (*Salmonella enterica* subsp. *enterica* serovar Senftenberg, *Escherichia coli*, *Yersinia enterocolitica*, *Staphylococcus aureus*, *Enterococcus faecium*, *Listeria monocytogenes*, *Bacillus subtilis*)	1,25 – 10 $\mu L/mL$ 0,2 $\mu L/mL$	Cherrat et al. (2013)
Antioxidant	Leaves	HD essential oil and SFME volatile extract	Stimulated mice peritoneal neutrophils	6,65–13,75 mg/mL	Bendjersi et al. (2015)
Insecticidal	Leaves	Essential oil	Repellency bioassay (*Rhyzopertha dominica, Tribolium castaneum*)	2, 4—6 ml	Jemaa et al. (2012)
Antioxidant *Antimicrobial*	Leaves	Essential oil and hydrolates	DPPH and ABTS assay Microdiluition and the disc diffusion method (*Escherichia coli, Pseudomonas fluorescens, Acinetobacter bohemicus, Bacillus cereu, Kocuria marina*	100 µg/mL to 0.049 µg/mL	Ovidi et al. (2021)
Alcohol Absorption Inhibitors	Leaves	Methanolic extract	Oral ethanol-loaded rat	125 to 500 mg/kg	Yoshikawa et al. (2000)
Antimicrobical *Antifungal* *Cytotoxic*	Leaves	Acetone, Ethanol, Methanol and Aqueous extracts	Well diffusion method (*Enterococcus faecalis, Staphylococcus aureus, Streptococcus pneumoniae, Proteus mirabilis* and poisoned food method (*Fusarium solani, Fusarium oxysporum, Alternaria alternata, Bipolaris* sp.)	0,125 mg/ml -32 mg/ml (MIC and MBC values for bacteria and fungi ranged from 8 to > 32 mg/mL.)	Rizwana et al. (2019)
Antimicrobical *Antifungal*	Leaves	Iron oxide nanoparticles in the phase of hematite (α-Fe_2O_3) by the aqueous extract	The disc diffusion method (Gram-positive bacterium of *Listeria monocytogenes* and the fungi *Aspergillus flavus* and *Penicillium spinulosum*)	30 mL	Jamzad et al. (2020)
Antioxidant *Cytotoxic*	Leaves	Hydroalcoholic extract	SK-N-BE(2)C neuronal and HepG2 hepatic cell lines	3,125, 6,25, 12,5 e 25,0 $\mu g/mL$ (RACI = 0,93)	Brahmi et al. (2015)
Antioxidant *Restoring Cholinergic dysfunction*	Leaves	Bay leaf incense (BL)	Recognition and measurement of the Biochemical Parameters: AChE, superoxide dismutase (SOD), and catalase (CAT) specific activities, the total content of reduced glutathione (GSH), protein carbonyl, and malondialdehyde (MDA). Sco -induced rat model	0,7 mg/kg	Brinza et al. (2021)

Table 4 continued

Activity	Plant organ	Extract	Method (target organism)	Tested concentration	References
Antioxidant	Leaves	Dried-bay leaves	Blood and lenses rabbits under fat-enriched diet	1 g/Kg	Casamassima et al. (2016)
Antioxidant	Leaves	Methanol extract and aqueous extracts	ABTS radical scavenging assay	1 g	Oudjedi et al. (2018)
Antioxidant	Leaves	Methanolic and ethanolic extract	Free radical scavenging activity by DPPH assay metod and FRM		Chandrashekhara and Rekha (2017)
Antioxidant	Leaves	Hexane and methanol–water 1:1 extract	ABTS radical scavenging assay	0,46 ± 0,04 mM TE/g	de Falco et al. (2018)
Radical scavenging			DPPH radical scavenging assay	0,27 ± 0,001 mM TE/g	
Antioxidant	Leaves	Acetone extract	BSA, DPPH, superoxide anion radical scavenging assay	0,10 e 0,06 mg/mL	Kazeem et al. (2015)
Cytotoxic				1000–2000 $\mu g/ml$	
Phytotoxicity				640–1640 $\mu g/ml$	
Antioxidant	Leaves	Ethanolic and aqueous extracts	2,2-diphenyl-picrilhydrazyl (DPPH) discoloration method		Vardapetyan et al. (2013)
Antioxidant	Leaves, roots, branches	Acetonic extract	Phosphomolybdenum method	125 mL	Ouchikh et al. (2010)
Antioxidant	Leaves	70% EtOH extract	DPPH Assay, Bovine Brain Peroxidation Assay and β-Carotene Bleaching Test	IC_{50} = 1 m g/ml	Conforti et al. (2006)
Antioxidant *Radical scavenging*	Leaves	Water and ethanol extracts	DPPH· free radical scavenging, superoxide anion radical scavenging, hydrogen peroxide scavenging and metal chelating activities	20, 40, and 60 $\mu g/mL$	Elmastaş et al. (2006)
Antiviral	Leaves	Ethanolic extract	Infected BQCV honeybees virus	1 mg/mL (≥ 5 mg/mL significant activity)	Aurori et al. (2016)
Inhibit nitric oxide (NO) production	Leaves	Methanolic extract	lipopolysaccharide (LPS)-activated mouse peritoneal macrophages	IC_{50} = 1.2–3.8 μM	Matsuda et al. (2000)
Inhibit NO production	Leaves	Methanolic extract	LPS—activated murine macrophages	0,1 $\mu g/mL$ (IC_{50} = 0,8 μm)	De Marino et al. (2005)
Inhibit microglial activation	Leaves	Sesquiterpenes	LPS-induced microglial activation	23.3, 39.9, 25.3, 22.0, 30.5, 14.0, 35.4 μM	Chen et al. (2014)

For each extract, the experimental procedure used to test the activity is reported as well as the target organism if any

BQCV black queen cell virus, *SK-N-BE (2) -C* human bone marrow neuroblastoma cells, *HepG2* human hepatoblastoma cell line, *LPS* lypopolisaccharide, *Sco* scopolamine, *FRM* Ferric ion redn. method, *BSA* Bovine serum albumin, *SFME* solvent-free microwave extraction, *HD* hydrodistillation., *DPPH* 2,2-diphenyl-picrylhydrasyl

antifungal, antioxidant, insecticidal and nematicidal effects.

Antibacterial and antifungal activities were shown in several studies on a variety of bacteria and fungi (Table 4). Very recently, Nafis et al. (2020) evaluated antibacterial and antifungal effects in vitro of laurel essential oils in combination with the conventional antimicrobial drugs, fluconazole, ciprofloxacin, and vancomycin. The essential oil alone showed high activity with minimal inhibitory concentrations (MICs) ranging from 1.39 to 22.2 mg/mL for bacteria and between 2.77 and 5.55 mg/mL for yeasts. A synergistic effect was observed when essential oil was tested in combination with antibiotics with fractional inhibitory concentration (FIC) index values in the range of 0.266 to 0.75 for bacteria, and between 0.258 and 0.266 for yeast. Thus, this evidence could constitute the basis for further studies to treat antibiotic-resistant pathogens.

Caputo et al. (2017) studied the bioactivities of the essential oils. Antimicrobial and antifungal activities were demonstrated for essential oil and for 1,8-cineole in vitro. In addition, the cytotoxicity of the essential oil was tested against SH-SY5Y cell line, as well as the influence of the essential oil on the expression of adenylate cyclase 1 (ADCY1), suggesting possible oil effects on the Central Nervous System.

Insecticidal activity of the essential oil from Tunisia, Algeria and Morocco was reported against *Tribolium castaneum* and *Rhyzopertha dominica* Jemâa et al. (2012). Results showed that all tested oils were repellent and toxic to adult insects, being the activity dependent upon insect species and oil origin. Both in filter paper tests and in fumigant activity test, L. nobilis essential oil from Morocco showed high insecticidal activity compared to the oils from Tunisia and Algeria. Their work indicated the efficacy of laurel essential oil as insecticide and repellent against stored product pests. Nematicidal activity of bay leaf essential oil, its fractions, isolated and derivatized compounds was testes against the root-knot nematodes, *Meloidogyne* spp. (Chahal et al. 2017). Bay leaf essential oil and its fractions and derivatized compounds were effective to inhibit egg hatch and to increase the juvenile mortality at all concentrations tested and durations of the exposed trial. In particular, the bay leaf essential oil showed the highest egg hatch inhibition and mortality. The study revealed indicated the potential use of bay leaf essential oil against *M. incognita* and the needing of further studies to evaluate the nematicidal properties and understand the mechanism of action.

Several studied also reported antioxidant activity of essential oil tested by DPPH assay and as total reduction capacity Riabov et al. (2020), DPPH free radical scavenging and β-carotene/linoleic acid test systems (Chahal et al. 2017) DPPH and ABTS assay (Cherrat et al. 2014; Ovidi et al. 2021) and stimulated mice peritoneal neutrophils (Bendjersi et al. 2016).

Leaves extracts

The leaves of the plant were also subjected to a pharmacological screening. Antimicrobial activity and antifungal activity have been recently demonstrated by different research groups (Rizwana et al. 2019; Jamzad and Kamari Bidkorpeh 2020). Rizwana et al. (2019) evaluated the antibacterial and antifungal activity by extracting *L nobilis* leaves with solvents of increasing polarites. The acetone extract had the largest inhibition against *Streptococcus pneumoniae* (37.16 ± 0.23 mm) while ethanol and methanol extracts exhibited high inhibition against *Alternaria alternata* (91.33 ± 0.47; 90.66 ± 0.94). Jamzad and Kamari Bidkorpeh (2020) reported an approach by green nanotechnology based on the application of biomaterials in the synthesis of nanoparticles. Thus, iron oxide nanoparticles were synthesized in the phase of hematite (α-Fe_2O_3) by the aqueous extract of *L. nobilis* leaves in a simple and eco-friendly method. The obtained nanoparticles were tested against three bacteria and two fungi. The results showed that the nanoparticles were moderately effective on the Gram-positive bacterium of *Listeria monocytogenes* and the fungi *Aspergillus flavus* and *Penicillium spinulosum* and therefore could be of potential use as antibacterial and antifungal agents.

Rizwana et al. (2019) and Kazeem et al. (2015) also reported cytotoxic activity of the plant extracts, the last activity reported by Brahmi et al. (2015) on HepG2 hepatic cell lines.

However, many studies were related to the antioxidant activity of the organic and aqueous leaf extracts (Conforti et al. 2006; Elmastaş et al. 2006; Ouchikh et al. 2011; Vardapetyan et al. 2013; Brahmi et al. 2015; Kazeem et al. 2015; Casamassima et al. 2017;

Oudjedi et al. 2019; Brinza et al. 2021; deFalco et al. 2018).

In addition, (Brinza et al. 2021) investigated the ability of bay leaf incense (BL) to elicit the memory formation via the action on the cholinergic system using a scopolamine (Sco)-induced rat model. Thus, rats were exposed to BL over 5 min once daily for 22 days, whereas memory impairment was induced by Sco (0.7 mg/kg), a muscarinic receptor antagonist. The data obtained indicated that the exposure to BL significantly ameliorated Sco-induced cognitive impairment and oxidative stress in the rat hippocampus thus suggesting that BL-induced ameliorative cognitive effects are mediated by enhancement of the cholinergic system and antioxidant activities.

Antiviral activity of the *L. nobilis* leaf ethanolic extract has been reported by Aurori et al. (2016) on virus targeting bee. The authors performed the antiviral tests on forager honeybees naturally infected with BQCV (Black queen cell virus). Higher extract concentration ($\geq$ 5 mg/ml) significantly reduced virus replication although the activity was observed also at low concentrations. The evaluation of vitellogenin gene expression as an indicator of transcript homeostasis indicated constant RNA levels both before and after treatment. This data suggests that its expression was not impacted by the plant treatment.

Inhibition of nitrogen oxide (NO) production has been reported for the methanolic extract of the plant leaf on lipopolysaccharide-LPS activated mouse macrophages (Matsuda et al. 2000; De Marino et al. 2005). The methanol extract of laurel was shown to inhibit the nitric oxide production in mouse peritoneal macrophages activated with lipopolysaccharide (LPS). The activity was ascribable to sesquiterpene compounds that were further isolated and tested following a bioassay-guided separation. Among the isolated compounds, the sesquiterpene lactone showed the highest activity thus pointing to the importance of the α-methylene-γ-butyrolactone moiety as key structural element for the activity. Study of the mechanism further indicated inhibition of inducible nitric oxide synthase (iNOS) induction in accordance with induction of heat shock protein 72 (HSP 72). Therefore, they suggested that sesquiterpene lactones induce HSP 72 thereby preventing nuclear factor-κB activation followed by iNOS induction.

De Marino et al. (2004) further reported megastigmane and phenolic glucosides from leaves extract along with their effect on nitric oxide production in lipopolysaccharide-activated murine macrophages. Further studies indicated for the megastigmane glycoside, lauroside B, antiproliferative activity against three human melanoma cell lines, A375, WM115, and SK-Mel-28. The inhibition was due to the induction of apoptosis, as showed by FACS analysis with annexin V/PI staining, and confirmed by the activation of caspase-3 and by the cleavage of poly(ADP-ribose) polymerase (PARP). In addition, the exposure of human melanoma cells to lauroside B inhibited IκB-α degradation and constitutive NF-κB DNA-binding activity as well as the expression, regulated by NF-κB, of two antiapoptotic genes, XIAP and c-FLIP. Thus, lauroside B could be a promising drug candidate in human aggressive melanoma cell lines Panza et al. (2011).

Sesquiterpenes compounds from the leaves of laurel showed to inhibit microglial activation as reported by Chen et al. (2014). This activity could be of potential use for the treatment of neurodegenerative diseases. In effect, the leaves extract showed moderate inhibition on microglial activation while the test on the purified sesquiterpenes revealed these compounds as responsible of the observed inhibitory activities on LPS-induced microglial activation and therefore improving the human cognitive heath.

Conclusion

Laurel is an aromatic broadleaf evergreen tree or large shrub belonging to the Lauraceae family. It is a common plant originating and diffused in the Mediterranean basin. The plant has been used since ancient times as a food ingredient and traditional remedy mainly to help sleeping, as laxative, to reduce chest pains and inflammation of throat and tongue. Additionally, antipyretic, lowering fever and refreshing liver properties were also reported. Due to its wide use, the chemical composition and the biological activity of the plant have been largely studied. The essential oils and the plant leaf extracts were studied in detail with different methods. A rich content of metabolites including proteins, free sugars, organic acids, PUFA and tocopherols has been reported. In addition, several pharmacological studied scientifically demonstrated some of the activity known from traditional medicine including overall antimicrobial and antioxidant

properties. Thus, this review, reporting the existing studies on *L. nobilis* botany, traditional uses, chemistry, and pharmacology, may be exploited as scientific basis for further research.

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References

Abay G, Kılıç A (2001) Local names and ethnobotanical features of some plants in the district of Pırenbeleni and Yançktepe (Mersin). Herb J Syst Bot 8:97–104

Akdemir Evrendilek G (2015) Empirical prediction and validation of antibacterial inhibitory effects of various plant essential oils on common pathogenic bacteria. Int J Food Microbiol 202:35–41. https://doi.org/10.1016/j.ijfoodmicro.2015.02.030

Alarcón R, Pardo-De-Santayana M, Priestley C et al (2015) Medicinal and local food plants in the south of Alava (Basque Country, Spain). J Ethnopharmacol 176:207–224. https://doi.org/10.1016/j.jep.2015.10.022

Aleo M, Cambria S, Bazan G (2013) Tradizioni etnofarmacobotaniche in alcune comunità rurali dei Monti di Trapani (Sicilia occidentale). Quad Bot Ambient Appl 24:27–48

Ali-Shtayeh MS, Yaniv Z, Mahajna J (2000) Ethnobotanical survey in the Palestinian area: a classification of the healing potential of medicinal plants. J Ethnopharmacol 73:221–232. https://doi.org/10.1016/S0378-8741(00)00316-0

Amico FP, Sorce EG (1997) Medicinal plants and phytotherapy in Mussomeli area (Caltanissetta, Sicily, Italy). Fitoterapia (milano) 68(2):143–159

Arcidiacono S, Napoli M, Oddo G, Pavone P (2007) Piante selvatiche d'uso popolare nei territori di Alcara li Fusi e Militello Rosmarino (Messina N-E Sicilia). Quad Bot Ambient 18:105–146

Atzei AD, Orioni S, Sotgiu R (1991) Contributo alla conoscenza degli usi etnobotanici nella Gallura (Sardegna). Boll Della Soc Sarda Sci Nat 28:137–177

Aurori AC, Bobiş O, Dezmirean DS et al (2016) Bay laurel (Laurus nobilis) as potential antiviral treatment in naturally BQCV infected honeybees. Virus Res 222:29–33. https://doi.org/10.1016/j.virusres.2016.05.024

Axiotis E, Halabalaki M, Skaltsounis LA (2018) An ethnobotanical study of medicinal plants in the Greek islands of North Aegean Region. Front Pharmacol 9:1–6. https://doi.org/10.3389/fphar.2018.00409

Ballero M, Poli F, Sacchetti G, Loi MC (2001) Ethnobotanical research in the territory of Fluminimaggiore ž southwestern Sardinia

Barla A, Topçu G, Öksüz S et al (2007) Identification of cytotoxic sesquiterpenes from Laurus nobilis L. Food Chem 104:1478–1484. https://doi.org/10.1016/j.foodchem.2007.02.019

Barone R (1963) Le piante della medicina popolare nel territorio di Falconara e San lucido. Webbia 17:329–357. https://doi.org/10.1080/00837792.1963.10669749

Baydoun SA, Kanj D, Raafat K et al (2017) Ethnobotanical and economic importance of wild plant species of jabal moussa bioreserve. Lebanon J Ecosyst Ecography. https://doi.org/10.4172/2157-7625.1000245

Belasli A, Ben Miri Y, Aboudaou M et al (2020) Antifungal, antitoxigenic, and antioxidant activities of the essential oil from laurel (Laurus nobilis L.): Potential use as wheat preservative. Food Sci Nutr 8:4717–4729. https://doi.org/10.1002/fsn3.1650

Bellia G, Pieroni A (2015) Isolated, but transnational: The glocal nature of Waldensian ethnobotany, Western Alps. NW Italy J Ethnobiol Ethnomed. https://doi.org/10.1186/s13002-015-0027-1

Bendjersi FZ, Tazerouti F, Belkhelfa-Slimani R et al (2016) Phytochemical composition of the Algerian Laurus nobilis L. leaves extracts obtained by solvent-free microwave extraction and investigation of their antioxidant activity. J Essent Oil Res 28:202–210. https://doi.org/10.1080/10412905.2015.1129992

Bianchi A, Gallifuoco G et al (2004) Farmacopea Popolare Del Gargano. Natura l 32:54–66

Blanco E, Macía MJ, Morales R (1999) Medicinal and veterinary plants of El Caurel (Galicia, northwest Spain). J Ethnopharmacol 65:113–124. https://doi.org/10.1016/S0378-8741(98)00178-0

Boulila A, Hassen I, Haouari L et al (2015) Enzyme-assisted extraction of bioactive compounds from bay leaves (Laurus nobilis L.). Ind Crops Prod 74:485–493. https://doi.org/10.1016/j.indcrop.2015.05.050

Brahmi N, Scognamiglio M, Pacifico S et al (2015) 1H NMR based metabolic profiling of eleven Algerian aromatic plants and evaluation of their antioxidant and cytotoxic properties. Food Res Int 76:334–341. https://doi.org/10.1016/j.foodres.2015.07.005

Brickell C (ed) (2008) The royal horticultural society A-Z encyclopedia of garden plants. Dorling Kindersley, United Kingdom, p 612. ISBN 9781405332965

Brinza I, Boiangiu RS, Hancianu M et al (2021) Bay leaf (Laurus nobilis l.) incense improved scopolamine-induced amnesic rats by restoring cholinergic dysfunction and brain antioxidant status. Antioxidants 10:1–15. https://doi.org/10.3390/antiox10020259

Bruni A, Ballero M, Poli F (1997) Quantitative ethnopharmacological study of the Campidano Valley and Urzulei district, Sardinia, Italy. J Ethnopharmacol 57:97–124. https://doi.org/10.1016/S0378-8741(97)00055-X

Camangi F, Tomei PE (2003) Tradizioni etno-farmacobotaniche nella provincia di Livorno: il territorio della Valle Benedetta. Inf Bot Ital 35:41–54

Caputo L, Nazzaro F, Souza LF et al (2017) Laurus nobilis: Composition of essential oil and its biological activities. Molecules 22:1–11. https://doi.org/10.3390/molecules22060930

Casamassima D, Chiosi F, Vizzarri F et al (2017) The effect of Laurus nobilis on the blood and lenses antioxidant activity in rabbit under fat-enriched diet. Physiol Res 66:325–333. https://doi.org/10.33549/physiolres.933409

Chahal K, Kumar Singh D, Panchbhaiya A et al (2017) A review on chemistry and biological activities of Laurus nobilis L. essential oil. J Pharmacogn Phytochem JPP 6:1153–1161

Chandrashekhara S, Rekha S (2017) Comparative antioxidant activity of three herbal extracts. World J Pharm Res 6:1234–1240. https://doi.org/10.20959/wjpr20172-7812

Chen H, Xie C, Wang H et al (2014) Sesquiterpenes inhibiting the microglial activation from laurus nobilis. J Agric Food Chem 62:4784–4788. https://doi.org/10.1021/jf501515v

Cherrat L, Espina L, Bakkali M et al (2014) Chemical composition and antioxidant properties of Laurus nobilis L. and Myrtus communis L. essential oils from Morocco and evaluation of their antimicrobial activity acting alone or in combined processes for food preservation. J Sci Food Agric 94:1197–1204. https://doi.org/10.1002/jsfa.6397

Conforti F, Statti G, Uzunov D, Menichini F (2006) Comparative chemical composition and antioxidant activities of wild and cultivated Laurus nobilis L. leaves and Foeniculum vulgare subsp. piperitum (Ucria) coutinho seeds. Biol Pharm Bull 29:2056–2064. https://doi.org/10.1248/bpb.29.2056

Cornara L, La Rocca A, Marsili S, Mariotti MG (2009) Traditional uses of plants in the Eastern Riviera (Liguria, Italy). J Ethnopharmacol 125:16–30. https://doi.org/10.1016/j.jep.2009.06.021

Dall'Acqua S, Cervellati R, Speroni E et al (2009) Phytochemical composition and antioxidant activity of Laurus nobilis L. leaf infusion. J Med Food 12:869–876. https://doi.org/10.1089/jmf.2008.0119

Dall'Acqua S, Viola G, Giorgetti M et al (2006) Two new sesquiterpene lactones from the leaves of Laurus nobilis. Chem Pharm Bull 54:1187–1189. https://doi.org/10.1248/cpb.54.1187

da Silveira SM, Luciano FB, Fronza N et al (2014) Chemical composition and antibacterial activity of Laurus nobilis essential oil towards foodborne pathogens and its application in fresh Tuscan sausage stored at 7 C. LWT-Food Sci Technol 59:86–93. https://doi.org/10.1016/j.lwt.2014.05.032

De Cleene M, Lejeune MC (2003) Compendium of symbolic and ritual plants in Europe. Vol. I: trees and shrubs. pp 885, Man and Culture Publishers, Ghent

Dei Cas L, Pugni F, Fico G (2015) Tradition of use on medicinal species in Valfurva (Sondrio, Italy). J Ethnopharmacol 163:113–134. https://doi.org/10.1016/j.jep.2014.12.054

Della A, Paraskeva-Hadjichambi D, Hadjichambis AC (2006) An ethnobotanical survey of wild edible plants of Paphos and Larnaca countryside of Cyprus. J Ethnobiol Ethnomed 2:1–9. https://doi.org/10.1186/1746-4269-2-34

De Falco B, Fiore A, Rossi R et al (2018) Metabolomics driven analysis by UAEGC-MS and antioxidant activity of chia (Salvia hispanica L.) commercial and mutant seeds. Food Chem 254:137–143. https://doi.org/10.1016/j.foodchem.2018.01.189

De Vincenzi M, De Vincenzi A, Silano M (2004) Constituents of aromatic plants: elemicin. Fitoterapia 75:615–618. https://doi.org/10.1016/j.fitote.2004.05.003

Di Novella R, Di Novella N, De Martino L et al (2013) Traditional plant use in the National Park of Cilento and Vallo di Diano, Campania, Southern, Italy. J Ethnopharmacol 145:328–342. https://doi.org/10.1016/j.jep.2012.10.065

Di Sanzo P, De Martino L et al (2013) Medicinal and useful plants in the tradition of Rotonda, Pollino National Park, Southern Italy. J Ethnobiol Ethnomed 9:19

Di Stasi LC, Oliveira GP, Carvalhaes MA et al (2002) Medicinal plants popularly used in the Brazilian Tropical Atlantic Forest. Fitoterapia 73:69–91. https://doi.org/10.1016/S0367-326X(01)00362-8

Dias MI, Barros L, Dueñas M et al (2014) Nutritional and antioxidant contributions of Laurus nobilis L. leaves: Would be more suitable a wild or a cultivated sample? Food Chem 156:339–346. https://doi.org/10.1016/j.foodchem.2014.01.122

Duc Dat L, Viet Duc N, Thuy Luyen BT et al (2019) Megastigmane and abscisic acid glycosides from the leaves of Laurus nobilis L. Phytochem Lett 33:1–5. https://doi.org/10.1016/j.phytol.2019.06.011

Díaz-Maroto MC, Pérez-Coello MS, Cabezudo MD (2002) Effect of drying method on the volatiles in bay leaf (Laurus nobilis L.). J Agric Food Chem 50:4520–4524. https://doi.org/10.1021/jf011573d

El-Feraly FS, Benigni DA (1980) Sesquiterpene lactones of laurus nobilis leaves. J Nat Prod. https://doi.org/10.1021/np50010a016

Elmastaş M, Gülçin I, Işildak Ö et al (2006) Radical scavenging activity and antioxidant capacity of bay leaf extracts. J Iran Chem Soc 3:258–266. https://doi.org/10.1007/BF03247217

Ertuğ F (2004) Wild edible plants of the Bodrum area (Muğla, Turkey). Turk J Bot 28:161–174

Everest A, Ozturk E (2005) Focusing on the ethnobotanical uses of plants in Mersin and Adana provinces (Turkey). J Ethnobiol Ethnomed 1:1–6. https://doi.org/10.1186/1746-4269-1-6

Fakir H, Korkmaz M, Güller B (2009) Medicinal plant diversity of western Mediterrenean region in Turkey. J Appl Biol Sci 3:30–40

Fang F, Sang S, Chen KY et al (2005) Isolation and identification of cytotoxic compounds from Bay leaf (Laurus nobilis). Food Chem 93:497–501. https://doi.org/10.1016/j.foodchem.2004.10.029

Fidan H, Stefanova G, Kostova I et al (2019) Chemical Composition and Antimicrobial Activity of Laurus nobilis L. Essential Oils from Bulgaria. Molecules 24:1–10. https://doi.org/10.3390/molecules24040804

Foddis M, Foddis C, Maxia A (2006) Le piante utilizzate nella medicina popolare dell'Ogliastra (Sardegna Centro-Orientale) per la cura delle patologie del sistema muscoloscheletrico. Rend Del Semin Della Fac Di Sci Dell'università Di Cagliari 76:17–28

Fortini P, Di Marzio P, Guarrera PM, Iorizzi M (2016) Ethnobotanical study on the medicinal plants in the Mainarde Mountains (central-southern Apennine, Italy). J Ethnopharmacol 184:208–218. https://doi.org/10.1016/j.jep.2016.03.010

Ghantous A, Gali-Muhtasib H, Vuorela H et al (2010) What made sesquiterpene lactones reach cancer clinical trials? Drug Discov Today 15:668–678. https://doi.org/10.1016/j.drudis.2010.06.002

Guarrera PM (2003) Food medicine and minor nourishment in the folk traditions of Central Italy (Marche, Abruzzo and

Latium). Fitoterapia 74:515–544. https://doi.org/10.1016/S0367-326X(03)00122-9

Guarrera PM, Forti G, Marignoli S (2005) Ethnobotanical and ethnomedicinal uses of plants in the district of Acquapendente (Latium, Central Italy). J Ethnopharmacol 96:429–444. https://doi.org/10.1016/j.jep.2004.09.014

Guarrera PM, Lucia LM (2007) Ethnobotanical remarks on central and southern Italy. J Ethnobiol Ethnomed 3:1–11. https://doi.org/10.1186/1746-4269-3-23

Guarrera PM, Savo V, Caneva G (2015) Traditonal uses of plants in the Tolfa-Cerite-Manziate area (central Italy). Ethnobiol Lett 6:119–161. https://doi.org/10.14237/ebl.6.1.2015.288

Gürdal B, Kültür Ş (2013) An ethnobotanical study of medicinal plants in Marmaris (Muğla, Turkey). J Ethnopharmacol 146:113–126. https://doi.org/10.1016/j.jep.2012.12.012

Hibasami H, Yamada Y, Moteki H et al (2003) Sesquiterpenes (costunolide and zaluzanin D) isolated from laurel (*Laurus nobilis* L.) induce cell death and morphological change indicative of apoptotic chromatin condensation in leukemia HL-60 cells. Int J Mol Med 12:147–151. https://doi.org/10.3892/ijmm.12.2.147

Honda G, Yeşilada E, Tabata M et al (1996) Traditional medicine in Turkey VI. Folk medicine in West Anatolia: Afyon, Kutahya, Denizli, Mugla. Aydin Provinces J Ethnopharmacol 53:75–87. https://doi.org/10.1016/0378-8741(96)01426-2

Idolo M, Motti R, Mazzoleni S (2010) Ethnobotanical and phytomedicinal knowledge in a long-history protected area, the Abruzzo, Lazio and Molise National Park (Italian Apennines). J Ethnopharmacol 127:379–395. https://doi.org/10.1016/j.jep.2009.10.027

Ivanović J, Mišić D, Ristić M et al (2010) Supercritical CO2 extract and essential oil of bay (*Laurus nobilis* L.) - Chemical composition and antibacterial activity. J Serbian Chem Soc 75:395–404. https://doi.org/10.2298/JSC090303003I

Jamzad M, Kamari Bidkorpeh M (2020) Green synthesis of iron oxide nanoparticles by the aqueous extract of *Laurus nobilis* L. leaves and evaluation of the antimicrobial activity. J Nanostructure Chem 10:193–201. https://doi.org/10.1007/s40097-020-00341-1

Julianti E, Jang KH, Lee S et al (2012) Sesquiterpenes from the leaves of *Laurus nobilis* L. Phytochemistry 80:70–76. https://doi.org/10.1016/j.phytochem.2012.05.013

Kazan D (2007) Ethnobotany of Ortaca (Mŭgla). Mŭgla University Institute of Science and Technology. M.Sc. Thesis

Kazeem MI, Ashafa AOT, Nafiu MO (2015) Biological activities of three nigerian spices – *Laurus nobilis* linn, Murraya koenigii (L) spreng and Thymus vulgaris linn. Trop J Pharm Res 14:2255–2261. https://doi.org/10.4314/tjpr.v14i12.15

Kermath BM, Bennett BC (2014) Food plants in the Americas: a survey of the domesticated, cultivated, and wild plants used for human food in North, Central and South America and the Caribbean. 2014:1–1449

Kilic A, Hafizoglu H, Kollmannsberger H, Nitz S (2004) Volatile Constituents and Key Odorants in Leaves, Buds, Flowers, and Fruits of Laurus nobilis L. J Agric Food Chem 52:1601–1606. https://doi.org/10.1021/jf0306237

Komiya T, Yamada Y, Moteki H et al (2004) Hot water soluble sesquiterpenes [anhydroperoxy-costunolide and 3-oxo-eudesma-1,4(15),11(13)triene-12,6α-olide]isolated from laurel (*Laurus nobilis* L.) induce cell death and morphological change indicative of apoptotic chromatin condensation in leukemia ce. Oncol Rep 11:85–88. https://doi.org/10.3892/or.11.1.85

Leporatti ML, Corradi L (2001) Ethnopharmacobotanical remarks on the province of Chieti town (Abruzzo, Central Italy). J Ethnopharmacol 74:17–40. https://doi.org/10.1016/S0378-8741(00)00325-1

Leto C, Tuttolomondo T, La Bella S, Licata M (2013) Ethnobotanical study in the Madonie Regional Park (Central Sicily, Italy) - Medicinal use of wild shrub and herbaceous plant species. J Ethnopharmacol 146:90–112. https://doi.org/10.1016/j.jep.2012.11.042

Licata M, Tuttolomondo T, Leto C et al (2016) A survey of wild plant species for food use in Sicily (Italy) - results of a 3-year study in four Regional Parks. J Ethnobiol Ethnomed. https://doi.org/10.1186/s13002-015-0074-7

Lin X, Peng Z, Su C (2015) Potential anti-cancer activities and mechanisms of costunolide and dehydrocostuslactone. Int J Mol Sci 16:10888–10906. https://doi.org/10.3390/ijms160510888

Loi MC, Maxia L, Maxia A (2005) Ethnobotanical comparison between the villages of Escolca and Lotzorai (Sardinia, Italy). J Herbs Spices Med Plants 11:67–84. https://doi.org/10.1300/J044v11n03_07

Loi MC, Poli F, Sacchetti G et al (2004) Ethnopharmacology of Ogliastra (Villagrande Strisaili, Sardinia, Italy). Fitoterapia 75:277–295. https://doi.org/10.1016/j.fitote.2004.01.008

Luna-Herrera J, Costa MC, González HG et al (2007) Synergistic antimycobacterial activities of sesquiterpene lactones from Laurus spp. J Antimicrob Chemother 59:548–552. https://doi.org/10.1093/jac/dkl523

Maccioni S, Flamini G, Cioni PL et al (2008) Ricerche etnobotaniche in Liguria. La riviera Spezzina (Liguria Orientale). Atti Della Soc Toscana Di Sci Nat Mem Ser B 115:77–82

De Marino S, Borbone N, Zollo F et al (2004) Megastigmane and phenolic components from Laurus nobilis L. leaves and their inhibitory effects on nitric oxide production. J Agric Food Chem 52:7525–7531. https://doi.org/10.1021/jf048782t

De Marino S, Borbone N, Zollo F et al (2005) New sesquiterpene lactones from Laurus nobilis leaves as inhibitors of nitric oxide production. Planta Med 71:706–710. https://doi.org/10.1055/s-2005-864191

Martelli I, Braca A, Camangi F (2016) Tradizioni Etnofarmacobotaniche Nel Territorio Del Gabbro. Quad Mus St Nat Livorno 38:15–38

Marzouki H, Elaissi A, Khaldi A et al (2010) Seasonal and Geographical Variation of *Laurus nobilis* L. Essential Oil from Tunisia. Open Nat Prod J 2:86–91. https://doi.org/10.2174/1874848100902010086

Matsuda H, Kagerura T, Toguchida I et al (2000) Inhibitory effects of sesquiterpenes from bay leaf on nitric oxide production in lipopolysaccharide-activated macrophages: Structure requirement and role of heat shock protein induction. Life Sci 66:2151–2157. https://doi.org/10.1016/S0024-3205(00)00542-7

Mattalia G, Sõukand R, Corvo P, Pieroni A (2020) Blended divergences: local food and medicinal plant uses among Arbëreshë, Occitans, and autochthonous Calabrians living in Calabria, Southern Italy. Plant Biosyst 154:615–626. https://doi.org/10.1080/11263504.2019.1651786

Mautone M, De Martino L, De Feo V (2019) Ethnobotanical research in Cava de' Tirreni area, Southern Italy. J Ethnobiol Ethnomed 15:1–21. https://doi.org/10.1186/s13002-019-0330-3

Maxia A, Lancioni MC, Balia AN et al (2008) Medical ethnobotany of the Tabarkins, a Northern Italian (Ligurian) minority in south-western Sardinia. Genet Resour Crop Evol 55:911–924. https://doi.org/10.1007/s10722-007-9296-4

Mediouni Ben Jemâa J, Tersim N, Toudert KT, Khouja ML (2012) Insecticidal activities of essential oils from leaves of *Laurus nobilis* L. from Tunisia, Algeria and Morocco, and comparative chemical composition. J Stored Prod Res 48:97–104. https://doi.org/10.1016/j.jspr.2011.10.003

Menale B, De Castro O, Cascone C, Muoio R (2016) Ethnobotanical investigation on medicinal plants in the Vesuvio National Park (Campania, Southern Italy). J Ethnopharmacol 192:320–349. https://doi.org/10.1016/j.jep.2016.07.049

Menale B, De Castro O, Di Iorio E et al (2021) Discovering the ethnobotanical traditions of the island of Procida (Campania, southern Italy). Plant Biosyst. https://doi.org/10.1080/11263504.2021.1881643

Menale B, Muoio R (2014) Use of medicinal plants in the South-Eastern area of the Partenio Regional Park (Campania, Southern Italy). J Ethnopharmacol 153:297–307. https://doi.org/10.1016/j.jep.2014.02.039

Montesano V, Negro D, Sarli G et al (2012) Notes about the uses of plants by one of the last healers in the Basilicata Region (South Italy). J Ethnobiol Ethnomed. https://doi.org/10.1186/1746-4269-8-15

Motti R, Antignani V, Idolo M (2009) Traditional plant use in the phlegraean fields regional park (Campania, Southern Italy). Hum Ecol 37:775–782. https://doi.org/10.1007/s10745-009-9254-1

Motti R, Bonanomi G, Lanzotti V, Sacchi R (2020) The contribution of wild edible plants to the mediterranean diet: an ethnobotanical case study along the coast of campania (Southern Italy). Econ Bot 74:249–272. https://doi.org/10.1007/s12231-020-09504-1

Motti R, Motti P (2017) An Ethnobotanical Survey of Useful Plants in the Agro Nocerino Sarnese (Campania, Southern Italy). Hum Ecol 45:865–878. https://doi.org/10.1007/s10745-017-9946-x

Muñiz-Márquez DB, Martínez-Ávila GC, Wong-Paz JE et al (2013) Ultrasound-assisted extraction of phenolic compounds from *Laurus nobilis* L. and their antioxidant activity. Ultrason Sonochem 20:1149–1154. https://doi.org/10.1016/j.ultsonch.2013.02.008

Nabiha B, Abdelfateh EO, Faten K et al (2009) Chemical Composition and Antioxidant Activity of *Laurus nobilis* Floral Buds Essential Oil. J Essent Oil-Bearing Plants 12:694–702. https://doi.org/10.1080/0972060X.2009.10643777

Nafis A, Kasrati A, Jamali CA et al (2020) A comparative study of the in vitro antimicrobial and synergistic effect of essential oils from *Laurus nobilis* L. and *Prunus armeniaca* L. from Morocco with antimicrobial drugs: New approach for health promoting products. Antibiotics. https://doi.org/10.3390/antibiotics9040140

Napoli M (2008) The plants, rituals and spells that "cured" helminthiasis in Sicily. J Ethnobiol Ethnomed 4:1–19. https://doi.org/10.1186/1746-4269-4-21

Ouchikh O, Chahed T, Ksouri R et al (2011) The effects of extraction method on the measured tocopherol level and antioxidant activity of *L. nobilis* vegetative organs. J Food Compos Anal 24:103–110. https://doi.org/10.1016/j.jfca.2010.04.006

Oudjedi K, Manso S, Nerin C et al (2019) New active antioxidant multilayer food packaging films containing Algerian Sage and Bay leaves extracts and their application for oxidative stability of fried potatoes. Food Control 98:216–226. https://doi.org/10.1016/j.foodcont.2018.11.018

Ouelbani R, Bensari S, Mouas TN, Khelifi D (2016) Ethnobotanical investigations on plants used in folk medicine in the regions of Constantine and Mila (North-East of Algeria). J Ethnopharmacol 194:196–218. https://doi.org/10.1016/j.jep.2016.08.016

Ovidi E, Masci VL, Garzoli S (2021) Chemical composition and biological activities of *Pimenta richardii*. Flavour Fragr J 36:272–279. https://doi.org/10.1002/ffj.3642

Pacifico S, Gallicchio M, Lorenz P et al (2013) Apolar Laurus nobilis leaf extracts induce cytotoxicity and apoptosis towards three nervous system cell lines. Food Chem Toxicol 62:628–37. https://doi.org/10.1016/j.fct.2013.09.029

Pacini E, Sciannandrone N, Nepi M (2014) Floral biology of the dioecious species *Laurus nobilis* L. (Lauraceae). Flora Morphol Distrib Funct Ecol Plants 209:153–163. https://doi.org/10.1016/j.flora.2014.02.001

Palmese MT, Uncini Manganelli RE, Tomei PE (2001) An ethno-pharmacobotanical survey in the Sarrabus district (south-east Sardinia). Fitoterapia 72:619–643. https://doi.org/10.1016/S0367-326X(01)00288-X

Panza E, Tersigni M, Iorizzi M et al (2011) Lauroside B, a megastigmane glycoside from *Laurus nobilis* (bay laurel) leaves, induces apoptosis in human melanoma cell lines by inhibiting NF-κB activation. J Nat Prod 74:228–233. https://doi.org/10.1021/np100688g

Parthasarathy VA, Zachariah TJ, Chempakam B (2008) 24 Bay Leaf. Chemistry of Spices, p 426

Passalacqua NG, Guarrera PM, De Fine G (2007) Contribution to the knowledge of the folk plant medicine in Calabria region (Southern Italy). Fitoterapia 78:52–68. https://doi.org/10.1016/j.fitote.2006.07.005

Peixoto LR, Rosalen PL, Ferreira GLS et al (2017) Antifungal activity, mode of action and anti-biofilm effects of *Laurus nobilis* Linnaeus essential oil against Candida spp. Arch Oral Biol 73:179–185. https://doi.org/10.1016/j.archoralbio.2016.10.013

Petkova Z, Stefanova G, Girova T et al (2019) Phytochemical Investigations of Laurel Fruits (*Laurus nobilis*). Nat Prod Commun 14:1–10. https://doi.org/10.1177/1934578X19868876

Pieroni A (2000) Medicinal plants and food medicines in the folk traditions of the upper Lucca Province, Italy.

J Ethnopharmacol 70:235–273. https://doi.org/10.1016/S0378-8741(99)00207-X

Pieroni A, Nebel S, Quave C et al (2002) Ethnopharmacology of liakra: Traditional weedy vegetables of the Arbëreshë of the Vulture area in southern Italy. J Ethnopharmacol 81:165–185. https://doi.org/10.1016/S0378-8741(02)00052-1

Pieroni A, Quave CL (2005) Traditional pharmacopoeias and medicines among Albanians and Italians in southern Italy: A comparison. J Ethnopharmacol 101:258–270. https://doi.org/10.1016/j.jep.2005.04.028

Pieroni A, Quave CL, Santoro RF (2004) Folk pharmaceutical knowledge in the territory of the Dolomiti Lucane, inland southern Italy. J Ethnopharmacol 95:373–384. https://doi.org/10.1016/j.jep.2004.08.012

Riabov PA, Micić D, Božović RB et al (2020) The chemical, biological and thermal characteristics and gastronomical perspectives of *Laurus nobilis* essential oil from different geographical origin. Ind Crops Prod. https://doi.org/10.1016/j.indcrop.2020.112498

Rizwana H, Al Kubaisi N, Al-Meghailaith N et al (2019) Evaluation of Chemical Composition, Antibacterial, Antifungal, and Cytotoxic Activity of *Laurus nobilis* L Grown in Saudi Arabia. J Pure Appl Microbiol 13:2073–2085. https://doi.org/10.22207/JPAM.13.4.19

Rossi PG, Bao L, Luciani A et al (2007) (E)-methylisoeugenol and elemicin: Antibacterial components of *Daucus carota* L. essential oil against *Campylobacter jejuni*. J Agric Food Chem 55:7332–7336. https://doi.org/10.1021/jf070674u

Sakata K, Hagiwara H, Yagi A, Ina K (1989) The First Naturally Occurring 3-Octulose, D-Gluco- l-Glycero-3-Octulose, as the Main Constituent of *Laurus nobilis* Flush. Agric Biol Chem 53:2539–2541. https://doi.org/10.1080/00021369.1989.10869663

Sanna C, Ballero M, Maxia A (2006) Le piante medicinali utilizzate contro le patologie epidermiche in Ogliastra (Sardegna centro-orientale). Atti Della Soc Toscana Di Sci Nat Mem Ser B 113:73–82

Sargin SA, Büyükcengiz M (2019) Plants used in ethnomedicinal practices in Gulnar district of Mersin. Turk J Herb Med 15:100224. https://doi.org/10.1016/j.hermed.2018.06.003

Savo V, Caneva G, Maria GP, David R (2011) Folk phytotherapy of the Amalfi Coast (Campania, Southern Italy). J Ethnopharmacol 135:376–392. https://doi.org/10.1016/j.jep.2011.03.027

Scherrer AM, Motti R, Weckerle CS (2005) Traditional plant use in the areas of Monte Vesole and Ascea, Cilento National Park (Campania, Southern Italy). J Ethnopharmacol 97:129–143. https://doi.org/10.1016/j.jep.2004.11.002

Shimada A, Ueno H, Inagaki M, Yoshimitsu H (2020) Comparative studies of the biological activities of selected herbal extracts and phenolic compounds isolated from *Rosa gallica*. Zeitschrift Fur Naturforsch Sect C J Biosci 75:31–39. https://doi.org/10.1515/znc-2019-0117

Shokoohinia Y, Yegdaneh A, Amin G, Ghannadi A (2014) Seasonal variations of *Laurus nobilis* L. leaves volatile oil components in Isfahan. Iran Res J Pharmacogn 1:1–6

Signorini MA, Piredda M, Bruschi P (2009) Plants and traditional knowledge: An ethnobotanical investigation on Monte Ortobene (Nuoro, Sardinia). J Ethnobiol Ethnomed 5:1–14. https://doi.org/10.1186/1746-4269-5-6

Staub PO, Geck MS, Weckerle CS et al (2015) Classifying diseases and remedies in ethnomedicine and ethnopharmacology. J Ethnopharmacol 174:514–519. https://doi.org/10.1016/j.jep.2015.08.051

Stefanova G, Girova T, Gochev V et al (2020) Comparative study on the chemical composition of laurel (*Laurus nobilis* L.) leaves from Greece and Georgia and the antibacterial activity of their essential oil. Heliyon 6:e05491. https://doi.org/10.1016/j.heliyon.2020.e05491

Tabanca N, Avonto C, Wang M et al (2013) Comparative investigation of umbellularia californica and laurus nobilis leaf essential oils and identification of constituents active against aedes aegypti. J Agric Food Chem 61:12283–12291. https://doi.org/10.1021/jf4052682

Turk A, Ahn JH, Jo YH et al (2019) NF-κB inhibitory sesquiterpene lactones from Lebanese Laurus nobilis. Phytochem Lett 30:120–123. https://doi.org/10.1016/j.phytol.2019.02.003

Tuttolomondo T, Licata M, Leto C et al (2014a) Popular uses of wild plant species for medicinal purposes in the Nebrodi Regional Park (North-Eastern Sicily, Italy). J Ethnopharmacol 157:21–37. https://doi.org/10.1016/j.jep.2014.08.039

Tuttolomondo T, Licata M, Leto C et al (2014b) Ethnobotanical investigation on wild medicinal plants in the Monti Sicani Regional Park (Sicily, Italy). J Ethnopharmacol 153:568–586. https://doi.org/10.1016/j.jep.2014.02.032

Tuzlacı E, Erol MK (1999) Turkish folk medicinal plants. Part II: Egirdir (Isparta). Fitoterapia 70:593–610. https://doi.org/10.1016/S0367-326X(99)00074-X

Tuzlacı E, Tolon E (2000) Turkish folk medicinal plants, part III: Şile Istanbul. Fitoterapia 71:673–685. https://doi.org/10.1016/s0367-326x(00)00234-3

Ugulu I, Baslar S, Yorek N, Dogan Y (2009) The investigation and quantitative ethnobotanical evaluation of medicinal plants used around Izmir province, Turkey. J Med Plants Res 3:345–367. https://doi.org/10.5897/JMPR.9001216

Ugurlu E, Secmen O (2008) Medicinal plants popularly used in the villages of Yunt Mountain(Manisa-Turkey). Fitoterapia 79:126–131. https://doi.org/10.1016/j.fitote.2007.07.016

Uncini Manganelli RE, Tomei PE (1999) Ethnopharmacobotanical studies of the Tuscan Archipelago. J Ethnopharmacol 65:181–202. https://doi.org/10.1016/S0378-8741(98)00177-9

Vardapetyan H, Tiratsuyan S, Hovhannisyan A et al (2013) Phytochemical composition and biological activity of laurus Nobilis L. leaves collected from two regions of South Caucasus. J Exp Biol Agric Sci 1:45–51

Vitalini S, Puricelli C, Mikerezi I, Iriti M (2015) Plants, people and traditions: Ethnobotanical survey in the Lombard Stelvio National Park and neighbouring areas (Central Alps, Italy). J Ethnopharmacol 173:435–458. https://doi.org/10.1016/j.jep.2015.05.036

Vitalini S, Tomè F, Fico G (2009) Traditional uses of medicinal plants in Valvestino (Italy). J Ethnopharmacol 121:106–116. https://doi.org/10.1016/j.jep.2008.10.005

Vázquez FM, Suarez MA, Pérez A (1997) Medicinal plants used in the Barros Area, Badajoz Province (Spain).

J Ethnopharmacol 55:81–85. https://doi.org/10.1016/S0378-8741(96)01491-2

Yesilada E, Honda G, Sezik E et al (1993) Traditional Medicine in Turkey IV. Folk Medicine in the Mediterranean Subdivision. J Ethnopharmacol 39:31–38

Yeşilada E, Sezik E, Honda G et al (1999) Traditional Medicine in Turkey IX. J Ethnopharmacol 64:195–210. https://doi.org/10.1016/s0378-8741(98)00133-0

Yoshikawa M, Shimoda H, Uemura T et al (2000) Alcohol absorption inhibitors from bay leaf (*Laurus nobilis*): Structure-requirements of sesquiterpenes for the activity. Bioorganic Med Chem 8:2071–2077. https://doi.org/10.1016/S0968-0896(00)00127-9

Yılmaz B, Deniz İ (2017) The Effects of Cultivation Area and Altitude Variation on the Composition of Essential Oil of Laurus nobilis l. Grown in Eastern. Int J Second Metab, Western and Central Karadeniz Region. https://doi.org/10.21448/ijsm.370118