# Sage and Lavender Essential Oils

Subjects: Microbiology

Contributor: Barbara Speranza , Angela Guerrieri , Angela Racioppo , Antonio Bevilacqua , Daniela Campaniello , Maria Rosaria Corbo

Modern society is becoming more and more reluctant to use antibiotic or chemical compounds in food production and is demanding foods without what they perceive as artificial and harmful chemicals, including many used as antimicrobials and preservatives in food. Another big problem is the improper use of antibiotics, especially broad-spectrum ones, which has significantly contributed to increased antibiotic resistance in many microorganisms. As a consequence, the whole scientific world has recently concentrated numerous studies on the research of natural remedies capable of counteracting multidrug-resistant strains and fighting infections: the use of aromatic plants and their essential oils (EOs) as potential alternatives to conventional antimicrobials to extend shelf life and combat foodborne pathogens has heightened.

sage lavender essential oils antimicrobials

## 1. Introduction

Essential oils (EOs) can be defined as volatile secondary metabolites produced by plants possessing significant antiseptic, antibacterial, antiviral, antioxidant, anti-parasitic, antifungal and insecticidal activities [1]. Nowadays, about 17,500 species (belonging to *Lamiaceae*, *Rutaceae*, *Myrtaceae*, *Zingiberaceae*, and *Asteraceae*) have been recognized as producers of EOs, with more than 9000 plants known for their biological properties and about 1500 species used for their aroma and flavor [2]. More than 250 types of EOs, at a value of 8.8 billion USD estimated in 2022, are traded annually on the international market, and a prevision indicates that this value will grow up to 15.3 billion USD by the year 2027 [3].

At present, most of EOs-based products are exploited for their cosmetic, perfuming and aromatherapy properties [4], but EOs could be also a powerful tool to control food spoilage and pathogenic bacteria. In fact, inhibiting the growth of microorganisms through natural preservatives is becoming a great issue because modern society is becoming more and more reluctant to use antibiotic or chemical compounds in food production [5]. Another big problem is the improper use of antibiotics, especially broad-spectrum ones, which has significantly contributed to the increased antibiotic resistance in many microorganisms [6][7]. As a consequence, the whole scientific world has recently concentrated numerous studies about the research of natural remedies capable of counteracting the multidrug-resistant (MDR) strains and fighting infections; the use of aromatic plants and their metabolites to contain this phenomenon has also been promoted by the World Health Organization (WHO) [8].

EOs are volatile, liquid, limpid, lipid-soluble, rarely colored and soluble in organic solvents. They are complex mixtures comprising about 20–60 components at different concentrations; in general, they are characterized by two or three major components, mainly terpenes, terpenoids, phenolic compounds and phenylpropanoids (at a level of 20–70%), and other compounds, such as fatty acids, oxides and sulfur derivatives, present in traces [9]. The capability of the main components to form complexes with enzymes by inhibiting them, to have toxic effects on microbial membrane structure and integrity and/or to quench free radicals, makes EOs able to exert biological and antimicrobial properties [1][10][11].

Among aromatic plants, the genus *Salvia* includes about 900 species, thus representing the largest genus of the *Labiatae*/*Lamiaceae* family [12]. It is diffuse both in the Old and New Worlds: over 500 species in Central and South America, more than 250 species in Central Asia and the Mediterranean areas and almost 90 species in East Asia [5]. In Italy, it is found spontaneously only in the Mediterranean area, from Central to Southern Italy, especially in marginal arid and stony areas. In Northern Italy, it is rarely found in the wild state, but it is cultivated in greenhouses for culinary use. Due to its aromatic properties, the aerial parts of the shrub find predominantly application in cookery, but an important use of this plant concerns traditional medicine thanks to its therapeutic properties in the treatment of numerous disorders and diseases [12] and its well-known antimicrobial activity [5]. In fact, many *Salvia* species are cultivated exclusively for their secondary metabolites that are employed in the production of essential oils, pharmaceuticals, colorants, dyes, cosmetics and biocides. The analysis of literature data evidenced that *Salvia* plants have a wide range of pharmacological activities, including anti-cancer, anti-inflammatory, antinociceptive, antioxidant, antimicrobial, hypoglycemic, hypolipidemic and memory-enhancing effects [12]. It is commonly used to treat mild dyspeptic complaints such as heartburn and bloating, excessive sweating, inflammations (mouth, throat and skin), gastrointestinal problems, colds, coughs and toothache but can also be used against rheumatism and sexual debility in neurological treatments [12].

*Lavandula* spp. is one of the most cultivated plants in the world on account of its EO properties; several studies have shown both antimicrobial and biological activities [13][14]. This genus comprises 39 species with about 400 registered cultivars but also several hybrids [15]; among these, three species (*Lavandula angustifolia* Mill., *Lavandula x intermedia* Emeric ex Loisel and *Lavandula latifolia* Medicus) are cultivated just for the production of EOs and their commercial importance (estimated at 50 million dollars) in the pharmaceutical, food and cosmetic industries [16]. Its EOs are widely used in the perfume manufacturing (e.g., soaps, colognes, fragrances, lotions and other cosmetics) but also in the food industry as natural flavoring for beverages, ice cream, candy, baked goods and chewing gum. Recently, lavender EOs have found application in ceramics, paint coatings, porcelain and other technical goods production [16]. *L. angustifolia* is the most important species of this genus; it is diffuse and cultivated mainly in Europe, primarily in France and Northern Italy [17]. In Italy, it covers an area of about 137 ha of marginal and abandoned lands due to its resistance to climatic changes and diseases, especially in Piedmont, Trentino Alto Adige, Lombardy, Veneto, Emilia Romagna and Tuscany.

## 2. *Salvia officinalis* Essential Oils

### 2.1. Chemical Composition and Biological Properties

*Salvia officinalis* EO (SOEO) has an intense and aromatic scent, with sweet and herbaceous notes: it is a clear yellowish-green liquid. Its yield ranges from 0.07 to 6%, depending on balsams and similar resinous plant exudations [18]. Over 120 constituents have been identified in SOEO; its main components are ketones and monoterpene hydrocarbons, such as borneol, camphor, 1.8-cineole, camphene, limonene, α-pinene, β-pinene, α-thujone, β-thujone, α-humulene sesquiterpene derivatives and β-caryophyllene [19][20][21]. However, α-humulene, ledene, viridiflorol, manool, and sclareol were also recovered. According to the International Organization for Standardization [22], a high-quality SOEO should contain 3–8.5% trans-thujone (α-thujone) and 18–43% cis-thujone (β-thujone), even if a high content of this compound should be avoided due to its neurotoxic effect. Phenolic compounds, monoterpenoids and triterpenoids are usually extracted by aerial parts, whereas diterpenoids are the main compounds of roots [23]. The structure of the major components of SOEOs is shown in **Figure 1**.

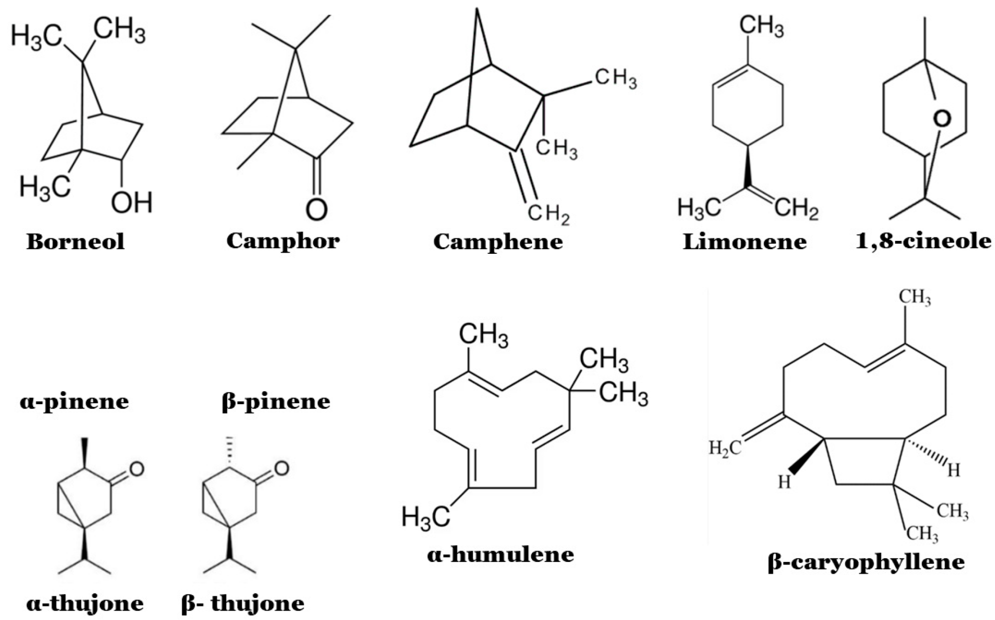


**Figure 1.** Structures of the major components of *Salvia officinalis* Essential Oils (SOEOs).

Similar to the other EOs, the composition of SOEOs is strongly correlated to their origins, and numerous extrinsic and intrinsic factors, such as agricultural practices, season, light, plant growth stage, etc., may play a significant role in their compositional characteristics [5].

In a recent study, Yilar and co-authors [24] analyzed the composition of three different EOs extracted from *S. officinalis* L., *S. cryptantha* and *S. tomentosa* collected in Turkey (Tokat province). The compositions showed distinct similarities in species, but all EOs resulted especially rich in terpenoid compounds, flavonoids and phenolic compounds; quinonoids were also recovered to a lesser extent. In particular, in *S. cryptantha* EO, 32 components were identified, predominantly eucalyptol (27.64%), camphor (29.87%), α-pinene (11.91%) and borneol (6.57%); an *S. tomentosa* EO contained 41 compounds, with the most abundant being β-thujene (40–69%), borneol (1.79–10.90%) and camphor (0.40–7.25%). Finally, in an *S. officinalis* EO, 31 components were identified, including 3-thujonene (31.95%), camphor (28.53%) and eucalyptol (7.35%). Similar results were also obtained for *S. officinalis* L. cultivated in Spain (Murcia Province) [25].

The genus name "*Salvia*" comes from Latin and means "to cure," while the name "*officinalis*" (also from Latin) means "medicinal" [26]; this makes us realize how this officinal plant has important biological properties. In ancient Rome, this plant was considered "sacred" due to its use to treat various diseases in popular medicine [27][28]. Evidence of its use is also present in ancient Egypt, Greece and Anglo-Saxon countries [29].

Today, the European Medicines Agency has proposed *S. officinalis* EO for oral use due to its anticancer and anti-inflammatory capabilities and for the treatment of several diseases such as dyspepsia, pharyngitis, stomatitis and inflammation in the mouth or throat [30]. In a study performed by Russo et al. [26], the anticancer activity was demonstrated to be correlated to the presence of α- and β-thujone isomers and other compounds (such as camphor), acting together in a synergistic action; these components are able to reduce side effects affecting cancer patients by inducing apoptotic cancer cell death.

The richness in terpenoids, flavonoids, phenolic compounds and quinonoids confers to SOEOs antibacterial, antifeedant, antioxidant, antiviral, antifungal, cytotoxic and antimicrobial properties [24][31][32] (**Figure 2**). Anti-inflammatory, antidiabetic and antimutagenic capacities suggest its use for dementia treatment [25].

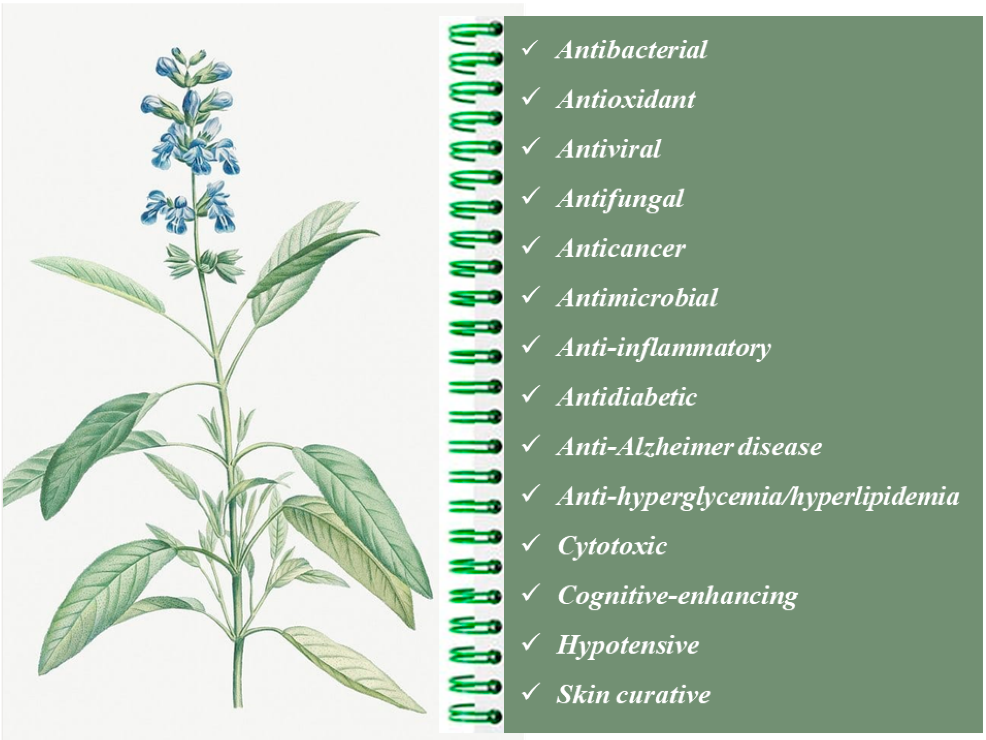


**Figure 2.** Main biological properties of *Salvia officinalis* Essential Oils (SOEOs).

The essential oils, oleoresins (solvent-free) and natural extractives (including distillates) of *S. officinalis*, *S. fruticosa*, *S. lavandulaefolia* and *S. sclarea* are generally recognized as safe for the Food and Drug Administration (USA), as well as in Europe, although the European Medicines Agency affirms that sage leaf is safe when used in recommended dosages, i.e., 3.5 and 6.6 mg/day (LD50 value equal to 2.6 g/kg); this recommendation considers the neurotoxic effect of thujone when present in high doses and establish that the amount of this compound in preparations needs to be clearly specified to permit a case-by-case benefit/risk analysis [33][34]. However, it was observed that prolonged use or overdose (corresponding to more than 15 g of the leaves) could cause some unwanted effects such as vomiting, salivation, tachycardia, vertigo, hot flushes, allergic reactions, tongue swallowing, cyanosis and convulsions [12]. Camphor, thujone and terpene ketones may also induce toxic effects on the fetus and newborn; thus, consumption of *S. officinalis* is not recommended in pregnancy and lactation [12].

Some *Salvia* plants produce other toxic compounds, such as the psychotropic molecule salvinorin A (produced by *S. divinorum*) which has dissociative, hallucinogenic and amnesiac effects. Also, red sage (*S. haematodes* Wall.) could have anticonvulsant effects and depress the central nervous system [23].

## 2.2. Antimicrobial Properties

The antibacterial activity of SOEOs has been reported by several authors. A quick look underlines a broad variability among the research, depending on the sensitivity of microorganisms and the efficiency of the tested components. Sage EO has shown antibacterial activity against *Escherichia coli*, *Bacillus subtilis*, *Salmonella* spp., *Listeria monocytogenes*, *Staphylococcus aureus*, *Staphylococcus epidermidis*, *Streptococcus mutans* and *Shigella sonnei*, highlighting good efficacy against both Gram-positive and Gram-negative bacteria [5]. However, Gram-positive bacteria have been observed to be more sensitive to sage EOs than other bacteria [5][19]. Its antimicrobial activity is attributed mainly to the presence of camphor, thujone and 1,8-cineole [35].

In 2018, Haziri and co-authors [36] reported that *S. officinalis* EO was active against *St. aureus*, *L. monocytogenes* and *E. coli*; the more significant effect was recorded for the growth of *St. aureus*. Similar results were observed by Mohamed and Mustafa [37], who tested sage EOs obtained through different extraction methods. In the same year, Medeiros de Almeida et al. [38] published a study on the antimicrobial activity of *S. officinalis* against five Gram-positive bacterial strains and five yeast strains, finding strong activity against *Streptococcus* strains and moderate activity against *Candida* strains. In 2019, an interesting study was performed by de Oliveira et al. [39], who tested sage EOs on microbial species responsible of oral disease and demonstrated that all the tested microorganisms were inhibited at a concentration of 50 mg/mL; but, by halving the concentration (25 mg/mL), the extract was effective on just over half of the target microorganisms (58.3%), suggesting a dose-dependent effect.

Despite the fact that several studies have been performed on the use of sage EO to inhibit microbial growth, there have been limited studies about its use in combination with other antimicrobial compounds. Recently, Mokhtari et al. [20] evaluated the antimicrobial activity of sage and thyme (*Thymus vulgaris* L.) and their mixture extracts. Sage exhibited the lowest antibacterial activity against *Bacillus cereus*, *St. aureus* and *E. coli* with inhibition zone diameters (i.z.d.) of 21.73, 19.12 and 16.76 mm, respectively. The antibacterial activity was improved when *Salvia* was combined with thyme: in this case, the i.z.d. were 31.25, 28.67 and 22.13 mm, respectively, probably due to the increased phenolic and flavonoid contents [20]. Sulaiman et al. [21] evaluated the antimicrobial activity of different sage EOs (commercial or extracted) and their synergistic effect with meropenem, an antibiotic with a broad spectrum of action and low toxicity for the treatment of severe and nosocomial infections [40]. The results highlighted that only the extracted EOs were effective against *E. coli* ATCC 25922, *L. monocytogenes*, *St. aureus*

ATCC 6538, *Streptococcus pyogenes* and *Pseudomonas aeruginosa* but not against *Klebsiella pneumoniae*, with i.z.d. of 18 ± 0.4, 16 ± 0.8, 15 ± 0.6, 14 ± 0.4, and 10 ± 0.2 mm, respectively. Concerning the interaction with meropenem, the authors reported that when the compounds were tested as single drugs against *Kl. pneumoniae* and *E. coli*, the MIC (minimum inhibitory concentration) values were 500 and 320 mg/mL for EOs and meropenem, respectively, but these values were reduced to 100 and 40 mg/mL when used in combination.

Besides *S. officinalis* L., other *Salvia* species are also able to influence microbial growth; for example, *Salvia sclarea* is a medicinal herb of the Mediterranean countries, known for its antidiabetic, anti-inflammatory, antimicrobial, antioxidant and antitumor properties [41]. In 2015, Cui and co-workers [41] studied the antibacterial activity and the mode of action of *S. sclarea* EO against seven pathogens: *E. coli*, *St. aureus*, *Bacillus pumilus*, *Kl. pneumoniae*, *B. subtilis*, *Salmonella* Typhimurium and *Ps. aeruginosa*. The oil was effective against all tested strains, showing a MIC of 0.05 and a minimum bactericide concentration (MBC) of 0.1%. The antimicrobial activity was also tested on the growth of *E. coli* in phosphate-buffered saline (PBS) and meats (chicken, pork and beef). The pathogen population was reduced by approx. 99.99% in all the conditions tested. Concerning the mode of action, the authors speculated that the effect was probably due to damage to the cell membrane, with a consequent alteration of permeability and leakage of intracellular material such as ATP and DNA [41].

*Salvia hispanica* L. is also known as “chia”, a name acquired from indigenous South Americans; it originated between Mexico and Guatemala and was cultivated in Central America. Thanks to their high nutritional value and fiber content, chia seeds are widely used in medicine and in food preparations because the extracted oil is characterized by a high content of proteins, antioxidants and polyphenols; moreover, their antibacterial and antiviral activity against various microorganisms has also been demonstrated [42][43]. For example, Elshafie et al. [43] tested the antimicrobial activity of chia against 4 Gram-positive bacteria, 6 Gram-negative bacteria and 10 fungi. Chia EO was more effective against Gram-positive than Gram-negative bacteria, and the antimicrobial activity was dose-dependent; in fact, the most effective inhibition resulted at the maximum concentration of the oil. Regarding the antifungal activity, chia EOs strongly inhibited *Aspergillus fumigatus*, *Penicillium expansum*, *Monilinia laxa* and *Monilia fructigena*. The antimicrobial activity was probably due to the presence of caryophyllene, a sesquiterpene volatile fraction that was able to affect the permeability of the bacterial membrane; however, the exact mode of antimicrobial action is still unknown and under investigation [44].

*Salvia miltiorrhiza*, also known as red sage, is mainly composed of hydrophilic compounds (salvianolic acids) and lipophilic compounds (tanshinones); these compounds have shown antimicrobial activities against Gram-positive and Gram-negative bacteria and fungi [45]. Chen et al., 2021 [46] reported that crypto-tanshinone (CT) exhibited a bacteriostatic against three strains of *St. aureus and* one of *B. subtilis*. The MIC values were between 4 and 16 µg/mL; the MBC > 64 µg/mL for each microorganism, and the MBC/MIC ratios were > 4. The authors hypothesized an involvement of this compound (CT) in the respiratory chain as an inhibitory agent since it did not damage the bacterial membrane but rapidly dissipated the membrane potential; the mechanisms of its antibacterial activity need further investigation. In a recent study, Lim Ah Tock et al. [47] compared the antimicrobial activity of *Salvia africana-lutea*, *Salvia lanceolata* and *Salvia chamelaeagnea* (also known as golden sage, rusty sage and rough blue sage, respectively) against three Gram-positive bacteria (*St. aureus*, *B. cereus* and *B. subtilis*) and four Gram-negative bacteria (*Acinetobacter baumannii*, *E. coli*, *Enterococcus faecium* and *Ps. aeruginosa*). The authors observed that the best performances were achieved by *S. chamelaeagnea* extracts, probably due to the presence of carnosol and carnosic acid, two antimicrobial compounds not detected in *S. africana-lutea* and *S. lanceolata* [47] [48].

# 3. *Lavandula* Essential Oils

## 3.1. Chemical Composition and Biological Properties

The *Lavandula* EO (LEO) is yellow and has an intense floral scent; it is obtained mainly by steam or hydro-distillation (yield is about 3%), and its composition varies greatly among different species and within the same species too, depending on the genotype, seasonal and climatic conditions, location, extraction methods and drying [49]. Even if over hundreds of chemical compounds can be recovered, the major components of *Lavandula* are oxygenated monoterpenes, monoterpene hydrocarbons and sesquiterpenes, mainly linalool (27.3–42.2%), linalyl acetate (27.2–46.6%), (Z)-β-ocimene (0.2–11.6%), terpinen-4-ol (0.70–4.6%), lavandulyl acetate (0.50–4.8%), β-caryophyllene (1.8–5.1%), (E)-β-ocimene (0.30–3.8%), α-terpineol (0.30–2.0%) and 1,8-cineole (0.10–1.2%) [49][50] (**Figure 3**). The contents of linalool and linalyl acetate determines the quality of the oil; on the other hand, due to the very strong influence on the scent, the contents of ocymen, cineole, camphor or terpin-4-ol should be low [35].

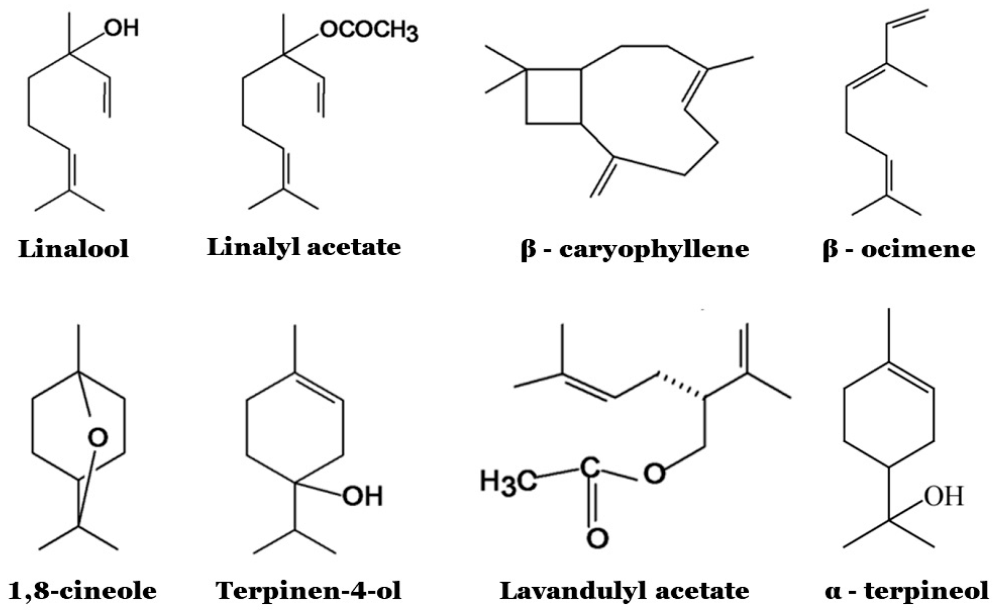


**Figure 3.** Structures of the major components of *Lavandula* Essential Oils (LEOs).

The oxygenated monoterpenes are responsible for the precious scent of lavender, variable from the sweet, floral, herbaceous and refreshing odor of the true lavender EO to the warm, slightly fruity and camphorous fragrance of *L. stoechas* EO until the atypical, more floral with a warm, rosy note and not herbaceous aroma of *L. heterophylla* Goodwin Creek [50]. An interesting overview of the chemistry of LEO, exploiting the characteristic chemical constituents and chemotypes of seventeen *Lavandula* species, can be found in the work of Aprotosoaie et al. [50].

As mentioned above, many factors may influence the chemical composition of LEO. In a study performed on locally grown plants in western Romania (*L. angustifolia* and *L. intermedia*), it was observed that the EO of *L. angustifolia* Miller contained 22 components (99.9% of the total), the main ones being caryophyllene (24.1%), β-phellandrene (16%) and eucalyptol (15.6%), while the EO of *L. intermedia* contained 24 components (98.26% of the total), mainly camphor (32.7%) and eucalyptol (26.9%) [51]. With respect to what is observed in the literature, where the major components of *Lavandula* are linalool and linalyl acetate, in the composition of the EOs analyzed in this research, these compounds were not found, underlining the great impact of environmental conditions (location and season) on the EO composition [49]. Contrarily, Turgut and co-workers [16], in their study about *L. angustifolia* Mill. grown in Burdur Örtülü locality (Turkey), found that linalool, linalyl acetate and α-terpineol were the most representative compounds (42.22%, 23.12% and 4.91%, respectively). A similar composition was found by Blažeković and coauthors [52] for EO of *L. angustifolia* cultivated in Croatia.

In 2017, an Italian study evidenced the effect of the growing season of organic lavender (*L. angustifolia*) and lavandin (*L. hybrida*) under the pedo-climatic conditions of central Italy by highlighting significant variations in EO composition that affected all the classes of compounds, except for oxygenated monoterpenes [53].

Since ancient times, *Lavandula* spp. and its EOs have been used in popular medicine as a natural remedy [54]. Over the years, it has been studied for its high content of bioactive compounds able to exert beneficial effects on human health and well-being. In particular, the richness in phenolic compounds confers to lavender EOs a high antioxidant activity due to a protective effect against the oxidative damage caused by free radicals [16]. The production of free radicals is a physiological event normally occurring in our bodies: a certain number of free radicals is essential to protect us from infections by viruses and bacteria, but an excessive amount of ROS (oxygen free radicals) is harmful since it could cause damage to various macromolecules (such as DNA, proteins, carbohydrates, lipids and enzymes), establishing a condition of oxidative stress, that is a risk factor for human health leading to cellular aging, inflammatory pathologies and degenerative diseases [49].

LEOs possess numerous biological activities such as antispasmodic, carminative, analgesic, sedative, hypotensive, antiseptic, antimicrobial, antifungal, antidiuretic and general tonic action [52]. In addition, anticholinesterase, anti-epileptogenic, neuroprotective, anxiolytic, anti-depressive, hyaluronidase and lipoxygenase inhibitory activities were also reported [49]. **Figure 4** synthesizes all recognized biological properties of LEOs that suggest their potential addition to food to improve consumers' health.


**Figure 4.** Main biological properties of *Lavandula* Essential Oils (LEOs).

Due to its action against lipid peroxidation, LEO is often suggested in the treatment of patients with rhinitis as potential natural medicine [55]. In a study carried out by Cardia and co-workers [56], the results highlighted that LEO was able to inhibit the release of important inflammatory mediators, particularly IL-1β and nitric oxide, and myeloperoxidase activity, showing significant anti-inflammatory activity. A wound-healing effect by increasing collagen synthesis and differentiation of fibroblasts through the up-regulation of transforming growth factor beta (TGF-β) was also demonstrated [57].

Toxicity from the use of lavender is uncommon, and LEO did not demonstrate cytotoxicity both in vitro and in vivo (mice); oral administration was considered safe with an LD50 of 13.5 g/kg [56]. However, some studies indicated that prolonged exposure to linalool (LEO main component) may result in allergic reactions: this is why the 7th Amendment of the European Cosmetics Legislation requires natural products, including linalool, to be labeled as potentially allergenic [56]. Contrarily, linalyl acetate may have aneugenic activity [58]. Genotoxicity in the proliferation of lymphocytes, damage to the cell membrane of human skin and contact dermatitis have been reported as adverse effects [56]. However, all these aspects are still under investigation, and efforts should be made in this direction to favor a widespread use, especially in clinical trials exploiting the use of LEO in improving the health of adult patients in various clinical settings and conditions.

## 3.2. Antimicrobial Properties

There is an extensive literature on the antimicrobial properties of LEO, but drawing unequivocal conclusions is difficult since there is no composition consistency, being influenced by variety, growing season and geographical location. In general, the literature shows that the chemical compound responsible for the antimicrobial and antifungal activity of LEO is linalool. LEOs have demonstrated antimicrobial activity against both Gram-positive and Gram-negative bacteria, yeasts and molds, with controversial results.

For example, a recent study performed in Saudi Arabia [59] tested the EO hydrodistilled from flowering aerial parts of *L. pubescens* Decne against thirteen strains of Gram-positive and Gram-negative bacteria using the agar diffusion assay. The oil showed good effectiveness, especially against *Ac. baumannii*, *Salm.* Typhimurium, *Sh. sonnei*, *Enterococcus faecalis* and *St. epidermidis*. The authors also tested carvacrol (the major constituent of lavender oil, 55.7%) by comparing it to some conventional antibiotics, i.e., vancomycin, amikacin and ciprofloxacin. The results revealed that Gram-negative strains were more susceptible than the Gram-positive ones. Contrarily, the Gram-positive bacteria turned out to be the most vulnerable to EOs recovered by the flower essential oil of lavender grown in Poland [60].

In 2017, Hossain et al. [61] tested the effectiveness of an EO extracted by flowers of *L. angustifolia* grown in Bulgaria against thirty-eight strains of turtle-borne pathogenic bacteria belonging to seven species: *Aeromonas hydrophila*, *Aeromonas caviae*, *Aeromonas dhakensis*, *Citrobacter freundii*, *Proteus mirabilis*, *Salmonella enterica* and *Ps. aeruginosa*. The results revealed that LEO was active against all tested bacteria except *Ps. aeruginosa*. Contrarily, a study performed on EO by *L. angustifolia* grown in Burdur Örtülü (Turkey) revealed significant effectiveness against this pathogen being able to eliminate contamination completely [16]. A good antimicrobial activity was also observed against *Candida albicans*, *St. aureus* and *Aspergillus brasiliensis* [16].

In 2021, significant inhibition of the growth of *B. subtilis* and *E. coli* was recorded by Caprari and co-workers [62] in their study about the use of EOs extracted from dried and fresh flowers of *Lavandula angustifolia* L. grown in central Italy. In addition, a bactericidal effect on *E. coli* was observed, particularly when oil from fresh flowers was used at the highest concentrations. However, apart from antimicrobial assays, this research is noteworthy because it reports the first evaluation of lavender EOs as a green method to control biodeterioration phenomena on a historical artistic wood painting (“Madonna con Bambino”, XIX century, located on the inner wall of the S. Maria del Lago church at Pesche in Isernia, Italy).

The effectiveness of LEOs could be improved if combined with other antimicrobial compounds. An interesting approach to the synergistic use of LEOs and other antimicrobials can be found in the study by Nafis et al. [63], who tested the efficacy of three EOs extracted from Moroccan lavender species (*L. pedunculata*, *L. angustifolia*, *L. maroccana*), combined with a conventional antibiotic (ciprofloxacin), against three pathogenic foodborne bacteria. EOs alone or combined showed remarkable antimicrobial activity against the tested bacteria with minimum inhibitory concentrations (MICs) ranging from 3.53 to 15.96 mg/mL, but when ciprofloxacin was added, the antibiotic MIC values were significantly lower (0.06 to 3.91 µg/mL). This synergism was more evident against *Salmonella* spp., suggesting that a mixture of lavender EOs is able to improve the efficacy of ciprofloxacin, which should be taken into consideration for a possible application in the pharmaceutical industries.

More recently, Aicha El Baabouaa et al. [64] evaluated the antibacterial activity of *Lavandula stoechas* L. EO (31.81% fenchone, 29.60% camphor, 13.14% terpineol, 8.96% menthone and 5.88% eucalyptol) against 11 multidrug-resistant strains of *Campylobacter* spp. Moreover, they studied its synergistic effect with two antibiotics (ampicillin and tetracycline) and examined the capability of *Campylobacter* strains to produce biofilm. The results showed that *Campylobacter* multidrug-resistant strains were much sensible to *L. stoechas* EO, with MIC values ranging from 0.063 to 0.25 µg/mL, depending on the strain. However, these values were significantly reduced during the combined use with antibiotics: MIC values ranged from 0.004 to 0.003 µg/mL with ampicillin and from 0.004 to 0.125 µg/mL with tetracycline, respectively. An impressive inhibitory impact of lavender oil on biofilm formation was also recovered.

## References


1. Chouhan, S.; Sharma, K.; Guleria, S. Antimicrobial activity of some Essential Oils-present status and future perspectives. Medicines 2017, 4, 58.
2. Mérillon, J.-M.; Rivière, C. Natural Antimicrobial Agents; Springer International Publishing AG: Cham, Switzerland, 2018.
3. Markets and Markets. Available online: https://www.marketsandmarkets.com/Market-Reports/essential-oil-market-119674487.html (accessed on 20 May 2023).
4. Swamy, M.K.; Sinniah, U.R. Patchouli (Pogostemon cablin Benth.): Botany, agrotechnology and biotechnological aspects. Ind. Crops Prod. 2016, 87, 161–176.
5. Sharifi-Rad, M.; Ozcelik, B.; Altın, G.; Daşkaya-Dikmen, C.; Martorell, M.; Ramírez-Alarcón, K.; Alarcón-Zapata, P.; Morais-Braga, M.F.B.; Carneiro, J.N.P.; Borges Leal, A.L.A.; et al. Salvia spp. plants-from farm to food applications and phytopharmacotherapy. Trends Food Sci. Technol. 2018, 80, 242–263.
6. Shariatifar, N.; Mostaghim, T.; Afshar, A.; Mohammadpourfard, I.; Sayadi, M.; Rezaei, M. Antibacterial properties of essential oil of Heracleum per-sicum (Golpar) and food-borne pathogens. Int. J. Enteric Pathog. 2017, 5, 41–44.
7. Hashempour-Baltork, F.; Hosseini, H.; Shojaee-Aliabadi, S.; Torbati, M.; Alizadeh, A.M.; Alizadeh, M. Drug Resistance and the Prevention Strategies in Food Borne Bacteria: An Update Review. Adv. Pharm. Bull. 2019, 9, 335–347.
8. Stan, D.; Enciu, A.-M.; Mateescu, A.L.; Ion, A.C.; Brezeanu, A.C.; Stan, D.; Tanase, C. Natural compounds with antimicrobial and antiviral effect and nanocarriers used for their transportation. Front. Pharmacol. 2021, 12, 723233.
9. Brnawi, W.I.; Hettiarachchy, N.S.; Horax, R.; Kumar-Phillips, G.; Ricke, S. Antimicrobial activity of leaf and bark cinnamon essential oils against Listeria monocytogenes and Salmonella

Typhimurium in broth system and on celery. J. Food Process Preserv. 2019, 43, e13888.

10. Krasniewska, K.; Gniewosz, M.; Kosakowska, O.; Pobiega, K. Chemical composition and antimicrobial properties of essential oil from lavender (Lavandula angustifolia L.) in commercial available preparation. Postępy Fitoter. 2017, 18, 113–118.
11. Swamy, M.K.; Akhtar, M.S.; Sinniah, U.R. Antimicrobial Properties of Plant Essential Oils against Human Pathogens and Their Mode of Action: An Updated Review. Evid. Based Complement. Alternat. Med. 2016, 2016, 3012462.21.
12. Ghorbani, A.; Esmaeilizadeh, M. Pharmacological properties of Salvia officinalis and its components. J. Tradit. Complement. Med. 2017, 7, 433–440.
13. Carrasco, A.; Thomas, V.; Tudela, J.; Miguel, M.G. Comparative study of GC-MS characterization, antioxidant activity and hyaluronidase inhibition of different species of Lavandula and Thymus essential oils. Flavour Fragr. J. 2016, 31, 57–69.
14. de Rapper, S.; Viljoen, A.; van Vuuren, S. The in vitro antimicrobial effects of Lavandula angustifolia essential oil in combination with conventional antimicrobial agents. Evid. Based Complement. Alternat. Med. 2016, 2016, 2752739.
15. Benabdelkader, T.; Zitouni, A.; Guitton, Y.; Jullien, F.; Maitre, D.; Casabianca, H.; Legendre, L.; Kameli, A. Essential oils from wild populations of Algerian Lavandula stoechas L.: Composition, chemical variability, and in vitro biological properties. Chem. Biodivers. 2011, 8, 937–953.
16. Turgut, A.C.; Emen, F.M.; Canbay, H.S.; Demirdöğen, R.E.; Çam, N.; Kılıç, D.; Yeşilkaynak, T. Chemical characterization of Lavandula angustifolia Mill. as a phytocosmetic species and investigation of its antimicrobia in cosmetic products. J. Turk. Chem. Soc. Sect. Chem. 2017, 4, 283–298.
17. Lis-Balchin, M. Lavender. In Handbook of Herbs and Spices; Peter, K.V., Ed.; Woodhead Publishing Limited: Cambridge, UK, 2012; Volume 2, pp. 329–347.
18. Fattahi, B.; Nazeri, V.; Kalantari, S.; Bonfill, M.; Fattahi, M. Essential oil variation in wild-growing populations of Salvia reuterana Boiss. collected from Iran, using GC–MS and multivariate analysis. Ind. Crops Prod. 2016, 81, 180–190.
19. Beheshti-Rouy, M.; Azarsina, M.; Rezaie-Soufi, L.; Alikhani, M.Y.; Roshanaie, G.; Komaki, S. The antibacterial effect of sage extract (Salvia officinalis) mouthwash against Streptococcus mutans in dental plaque: A randomized clinical trial. Iran. J. Microbiol. 2015, 7, 173–177.
20. Mokhtari, R.; Fard, M.K.; Rezaei, M.; Moftakharzadeh, S.A.; Mohseni, A. Antioxidant, antimicrobial activities, and characterization of phenolic compounds of Thyme (Thymus vulgaris L.), Sage (Salvia officinalis L.), and Thyme–Sage mixture extracts. J. Food. Qual. 2023, 2023, 2602454.

21. Sulaiman, A.M.; Abdulaziz, A.S.; Almutawea, A.M.; Alansari, S.A.; Aldoseri, F.A.; Bekhit, S.A.; Al-Thawadi, S.M.; Alqallaf, S.M.; Bekh, A.A. Evaluation of the antibacterial effect of Salvia officinalis Essential Oil and its synergistic effect with Meropenem. Lett. Appl. NanoBioScience 2023, 12, 44.
22. ISO 9909:1997; Oil of Dalmatian Sage (Salvia officinalis L.). International Organization for Standardization (ISO): Geneva, Switzerland, 1997.
23. Baricevic, D.; Bartol, T. The biological/pharmacological activity of the Salvia genus. In Sage, the Genus Salvia; Kintzios, S.E., Ed.; Harwood Academic Publishers: Singapore, 2005; p. 290.
24. Yilar, M.; Kadioğlu, I.; Telci, I. Chemical composition and antifungal activity of Salvia officinalis (L.), S. cryptantha (montbret et aucher ex benth.), S. tomentosa (mill.) plant essential oils and extracts. Fresenius Environ. Bull. 2018, 27, 1695–1706.
25. Cutillas, A.B.; Carrasco, A.; Martinez-Gutierrez, R.; Tomas, V.; Tudela, J. Salvia officinalis L. Essential Oils from Spain: Determination of Composition, Antioxidant Capacity, Antienzymatic, and Antimicrobial Bioactivities. Chem. Biodivers. 2017, 14, e1700102.
26. Russo, A.; Formisano, C.; Rigano, D.; Senatore, F.; Delfine, S.; Cardile, V.; Rosselli, S.; Bruno, M. Chemical composition and anticancer activity of essential oils of Mediterranean sage (Salvia officinalis L.) grown in different environmental conditions. Food Chem. Toxicol. 2013, 55, 42–47.
27. Durling, N.E.; Catchpole, O.J.; Grey, J.B.; Webby, R.F.; Mitchell, K.A.; Foo, L.Y.; Perry, N.B. Extraction of phenolics and essential oil from dried sage (Salvia officinalis) using ethanol–water mixtures. Food Chem. 2007, 101, 1417–1424.
28. Kamatou, G.P.P.; Makunga, N.P.; Ramogola, W.P.N.; Viljoen, A.M. South African Salvia species: A review of biological activities and phytochemistry. J. Ethnopharmacol. 2008, 119, 664–672.
29. Dweck, A.C. Introduction. The folklore and cosmetic use of various salvia species. In Sage, the Genus Salvia; Kintzios, S.E., Ed.; Harwood Academic Publishers: Singapore, 2005.
30. Monsen, R.E.; Herlofson, B.B.; Gay, C.; Fjeld, K.G.; Hove, L.H.; Malterud, K.E.; Saghaug, E.; Slaaen, J.; Sundal, T.; Tollisen, A.; et al. A mouth rinse based on a tea solution of Salvia officinalis for oral discomfort in palliative cancer care: A randomized controlled trial. Support. Care Cancer 2021, 29, 4997–5007.
31. Lakhal, H.; Ghorab, H.; Chibani, S.; Kabouche, A.; Semra, Z.; Smati, F.; Abuhamdah, S.; Kabouche, Z. Chemical composition and biological activities of the essential oil of Salvia officinalis from Batna (Algeria). Der Pharm. Lett. 2013, 5, 310–314.
32. Abu-Darwish, M.S.; Cabral, C.; Ferreira, I.V.; Gonçalves, M.J.; Cavaleiro, C.; Cruz, M.T.; Albdour, T.H.; Salgueiro, L. Essential oil of common sage (Salvia officinalis L.) from Jordon: Assessment of safety in mammalian cells and its antifungal and anti-inflammatory potential. Biomed Res. Int. 2013, 2013, 538940.

33. European Medicines Agency (EMA). Assessment Report on Salvia fruticosa Mill Folium. EMA/HMPC/599992/2014. 2016. Available online: https://www.ema.europa.eu/en/documents/herbal-report/final-assessment-report-salvia-fruticosa-mill-folium_en.pdf (accessed on 15 May 2023).
34. European Medicines Agency (EMA). Assessment Report on Salvia officinalis L., folium and Salvia officinalis L., Aetheroleum EMA/HMPC/150801/2015. 2016. Available online: https://www.ema.europa.eu/en/documents/herbal-report/draft-assessment-report-salvia-officinalis-l-folium-salvia-officinalis-l-aetheroleum_en.pdf (accessed on 15 May 2023).
35. Wińska, K.; Mączka, W.; Łyczko, J.; Grabarczyk, M.; Czubaszek, A.; Szumny, A. Essential Oils as Antimicrobial Agents—Myth or Real Alternative? Molecules 2019, 24, 2130.
36. Haziri, A.; Faiku, F.; Mehmeti, A.; Kurteshi, K.; Haziri, I.; Rudhani, I. In vitro antibacterial properties of ethanol extract from Salvia officinalis (L.) plant growing wild in Kosovo. Biomed. J. Sci. Tech. Res. 2018, 2, 2578–2580.
37. Mohamed, A.Y.; Mustafa, A.A. In vitro anti-microbial activity of Essential Oils and other extracts from Salvia officinalis against some bacteria. Plant Sci. 2019; 2019040012, preprints.
38. Medeiros de Almeida, C.; de Souza Sales Rocha, E.A.L.; Ponchet Alves, É.; de Freitas Lima, R.; Wanderley Cavalcanti, Y.; Barbosa Gomes, R.C.; Vieira Pereira, J.; Melo de Brito Costa, E.M. In vitro evaluation of the antimicrobial potential of Salvia officinalis L. against oral pathogens. J. Health Sci. 2019, 21, 129–133.
39. de Oliveira, J.R.; Vilela, P.G.D.F.; Almeida, R.B.A.; de Oliveira, F.E.; Carvalho, C.A.T.; Camargo, S.E.A.; Jorge, A.O.C.; de Oliveira, L.D. Antimicrobial activity of noncytotoxic concentrations of Salvia officinalis extract against bacterial and fungal species from the oral cavity. Gen. Dent. 2019, 67, 22–26.
40. Steffens, N.A.; Zimmermann, E.S.; Nichelle, S.M.; Brucker, N. Meropenem use and therapeutic drug monitoring in clinical practice: A literature review. J. Clin. Pharm. Ther. 2021, 46, 610–621.
41. Cui, H.; Zhang, X.; Zhou, H.; Zhao, C.; Lin, L. Antimicrobial activity and mechanisms of Salvia sclarea Essential Oil. Bot. Stud. 2015, 56, 16.
42. Divyapriya, G.K.; Veeresh, D.J.; Yavagal, P.C. Evaluation of antibacterial efficacy of Chia (Salvia hispanica) seeds extract against Porphyromonas gingivalis, Fusobacterium nucleatum and Aggregatibacter actinomycetemcomitans. An in-vitro study. Int. J. Ayurveda Pharm. Res. 2016, 4, 22–24.
43. Elshafie, H.S.; Aliberti, L.; Amato, M.; De Feo, V.; Camele, I. Chemical composition and antimicrobial activity of chia (Salvia hispanica L.) Essential Oil. Eur. Food Res. Technol. 2018, 244, 1675–1682.

44. Moo, C.L.; Yang, S.K.; Osman, M.A.; Yuswan, M.H.; Loh, J.Y.; Lim, W.M.; Lim, S.H.; Lai, K.S. Antibacterial activity and mode of action of β-caryophyllene on Bacillus cereus. Pol. J. Microbiol. 2020, 69, 1–6.
45. Moon, K.; Cha, J. Enhancement of antioxidant and antibacterial activities of Salvia miltiorrhiza roots fermented with Aspergillus oryzae. Foods 2020, 9, 34.
46. Chen, B.-C.; Ding, Z.-S.; Dai, J.-S.; Chen, N.-P.; Gong, X.-W.; Ma, L.-F.; Qian, C.-D. New insights into the antibacterial mechanism of cryptotanshinone, a representative diterpenoid quinone from Salvia miltiorrhiza Bunge. Front. Microbiol. 2021, 12, 647289.
47. Lim Ah Tock, M.; Combrinck, S.; Kamatou, G.; Chen, W.; Van Vuuren, S.; Viljoen, A. Antibacterial screening, biochemometric and bioautographic evaluation of the non-volatile bioactive components of three indigenous South African Salvia species. Antibiotics 2022, 11, 901.
48. Jordán, M.J.; Lax, V.; Rota, M.C.; Lorán, S.; Sotomayor, J.A. Relevance of carnosic acid, carnosol, and rosmarinic acid concentrations in the in vitro antioxidant and antimicrobial activities of Rosmarinus officinalis (L.) Methanolic Extracts. J. Agric. Food Chem. 2012, 60, 9603–9608.
49. Salehi, B.; Mnayer, D.; Özçelik, B.; Altin, G.; Kasapoğlu, K.N.; Daskaya-Dikmen, C.; Sharifi-Rad, M.; Selamoglu, Z.; Acharya, K.; Sen, S.; et al. Plants of the Genus Lavandula: From Farm to Pharmacy. Nat. Prod. Commun. 2018, 13, 1385–1402.
50. Aprotosoaie, A.C.; Gille, E.; Trifan, A.; Luca, V.S.; Miron, A. Oils of Lavandula genus: A systematic review of their chemistry. Phytochem. Rev. 2017, 16, 761–799.
51. Jianu, C.; Pop, G.; Gruia, A.T.; Horhat, F.G. Chemical composition and antimicrobial activity of essential oils of lavender (Lavandula angustifolia) and lavandin (Lavandula x intermedia) grown in Western Romania. Int. J. Agric. Biol. 2013, 15, 772–776.
52. Blažeković, B.; Yang, W.; Wang, Y.; Li, C.; Kindl, M.; Pepeljnjak, S.; Vladimir-Knežević, S. Chemical composition, antimicrobial and antioxidant activities of essential oils of Lavandula × intermedia 'Budrovka' and L. angustifolia cultivated in Croatia. Ind. Crops Prod. 2018, 123, 173–182.
53. Pistelli, L.; Najar, B.; Giovanelli, S.; Lorenzini, L.; Tavarini, S.; Angelini, L.G. Agronomic and phytochemical evaluation of lavandin and lavender cultivars cultivated in the Tyrrhenian area of Tuscany (Italy). Ind. Crops Prod. 2017, 109, 37–44.
54. Başer, K.H.C.; Buchbauer, G. Handbook of Essential Oils, Science, Technology and Applications, 2nd ed.; Başer, K.H.C., Buchbauer, G., Eds.; CRC Press: Boca Raton, FL, USA, 2016.
55. Lu, H.; Li, H.; Lu, H.; Li, X.; Zhou, A. Chemical composition of lavender essential oil and its antioxidant activity and inhibition against rhinitis-related bacteria. Afr. J. Microbiol. Res. 2010, 4, 309–313.

56. Cardia, G.F.E.; Silva-Filho, S.E.; Silva, E.L.; Uchida, N.S.; Cavalcante, H.A.O.; Cassarotti, L.L.; Salvadego, V.E.C.; Spironello, R.A.; Bersani-Amado, C.A.; Cuman, R.K.N. Effect of lavender (Lavandula angustifolia) essential oil on acute inflammatory response. Evid. Based Complement. Altern. Med. 2018, 2018, 1413940.
57. Mori, H.M.; Kawanami, H.; Kawahata, H.; Aoki, M. Wound healing potential of lavender oil by acceleration of granulation and wound contraction through induction of TGF-beta in a rat model. BMC Complement. Altern. Med. 2016, 16, 144.
58. Di Sotto, A.; Mazzanti, G.; Carbone, F.; Hrelia, P.; Maffei, F. Genotoxicity of lavender oil, linalyl acetate, and linalool on human lymphocytes in vitro. Environ. Mol. Mutagen. 2011, 52, 69–71.
59. El-Said, H.; Ashgar, S.S.; Bader, A.; AlQathama, A.; Halwani, M.; Ascrizzi, R.; Flamini, G. Essential Oil Analysis and Antimicrobial Evaluation of Three Aromatic Plant Species Growing in Saudi Arabia. Molecules 2021, 26, 959.
60. Adaszyńska-Skwirzyńska, M.; Dzięcioł, M. Comparison of phenolic acids and flavonoids contents in various cultivars and parts of common lavender (Lavandula angustifolia) derived from Poland. Nat. Prod. Res. 2017, 31, 2575–2580.
61. Hossain, S.; Heo, H.; De Silva, B.C.J.; Wimalasena, S.H.M.P.; Pathirana, H.N.K.S.; Heo, G.J. Antibacterial activity of essential oil from lavender (Lavandula angustifolia) against pet turtle-borne pathogenic bacteria. Lab. Anim. Res. 2017, 33, 195–201.
62. Caprari, C.; Fantasma, F.; Divino, F.; Bucci, A.; Iorizzi, M.; Naclerio, G.; Ranalli, G.; Saviano, G. Chemical Profile, In Vitro Biological Activity and Comparison of Essential Oils from Fresh and Dried Flowers of Lavandula angustifolia L. Molecules 2021, 26, 5317.
63. Nafis, A.; Ouedrhiri, W.; Iriti, M.; Mezrioui, N.; Marraiki, N.; Elgorban, A.M.; Syed, A.; Hassani, L. Chemical composition and synergistic effect of three Moroccan lavender EOs with ciprofloxacin against foodborne bacteria: A promising approach to modulate antimicrobial resistance. Lett. Appl. Microbiol. 2021, 72, 698–705.
64. El Baaboua, A.; El Maadoudi, M.; Bouyahy, A.; Belmehdi, O.; Kounnoun, A.; Cheyadmi, S.; Ouzakar, S.; Skali Senhaji, N.; Abrini, J. Evaluation of the combined effect of antibiotics and essential oils against Campylobacter multidrug resistant strains and their biofilm formation. S. Afr. J. Bot. 2022, 150, 451–465.

Retrieved from https://encyclopedia.pub/entry/history/show/110014