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Review

Essential Oils of Lamiaceae Family Plants as Antifungals

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Abstract: The incidence of fungal infections has been steadily increasing in recent years. Systemic mycoses are characterized by the highest mortality. At the same time, the frequency of infections caused by drug-resistant strains and new pathogens e.g., *Candida auris* increases. An alternative to medicines may be essential oils, which can have a broad antimicrobial spectrum. Rich in the essential oils are plants from the Lamiaceae family. In this review are presented antifungal activities of essential oils from 72 Lamiaceae plants. More than half of these have good activity (minimum inhibitory concentrations (MICs) < 1000 μg/mL) against fungi. The best activity (MICs < 100) have essential oils from some species of the genera *Clinopodium*, *Lavandula*, *Mentha*, *Thymbra*, and *Thymus*. In some cases were observed significant discrepancies between different studies. In the review are also shown the most important compounds of described essential oils. To the chemical components most commonly found as the main ingredients include β-caryophyllene (41 plants), linalool (27 plants), limonene (26), β-pinene (25), 1,8-cineole (22), carvacrol (21), α-pinene (21), p-cymene (20), γ-terpinene (20), and thymol (20).

Keywords: Labiatae; fungi; *Aspergillus*; Cryptococcus; Penicillium; dermatophytes; β-caryophyllene; sesquiterpene; monoterpenes; minimal inhibitory concentration (MIC)

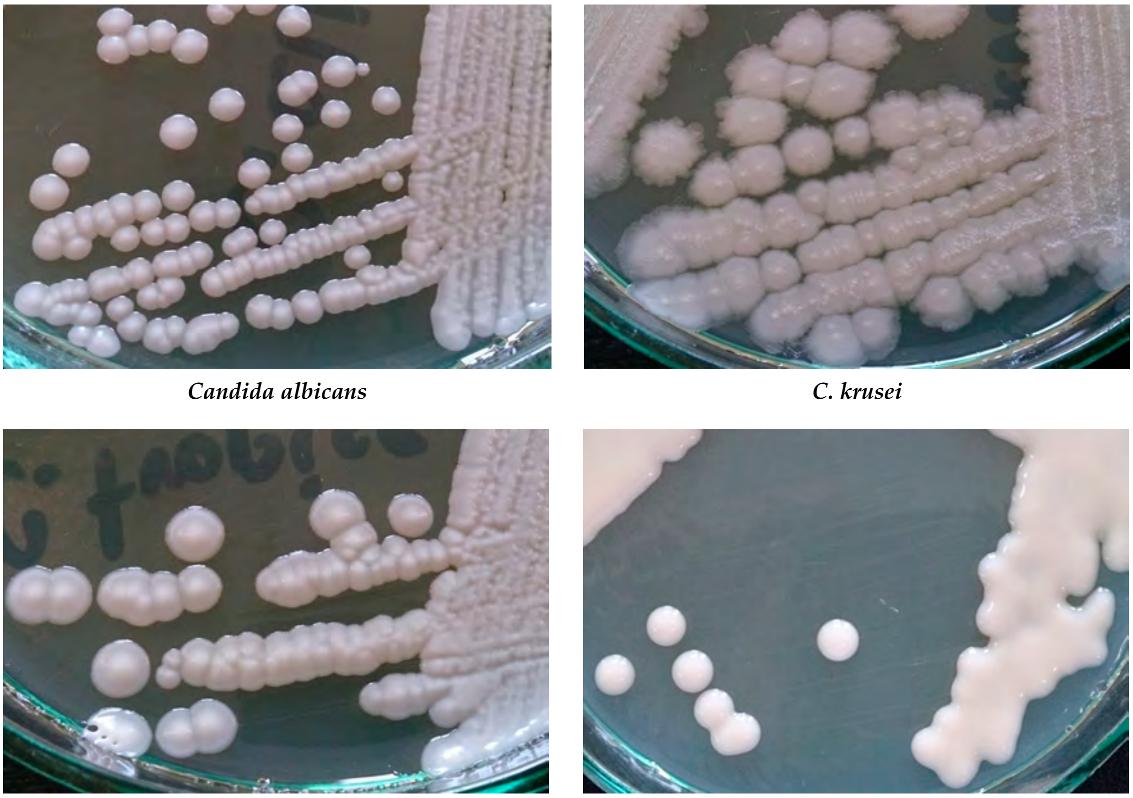
1. Introduction

Fungal infections belong to the most often diseases of humans. It is estimated that about 1.7 billion people (25% of the population) have skin, nail, and hair fungal infections [1]. The development of most of these infections is affected by dermatophytes, namely *Trichophyton* spp., *Microsporum* spp., and *Epidermophyton* spp. [2]. Simultaneously, mucosal infections of the oral and genital tracts caused by *Candida* spp. are very common. About 0.13 billion of women suffer from vulvovaginal candidiasis. On the other hand, oral candidiases are common in babies and denture wearers. Fungi also cause life-threatening systemic infections, with mortality reaching >1.6 million, which is >3-fold more than malaria [3]. Among life-threatening fungal infections prevail cryptococcosis (*Cryptococcus neoformans*) with >1,000,000 cases and mortality rate 20–70%, candidiasis (*Candida albicans*) with >400,000 cases and mortality rate 46–75%, pneumocystosis (*Pneumocystis jirovecii*) with >400,000 cases and mortality rate 20–80%, and aspergillosis (*Aspergillus fumigatus*) with >200,000 cases and mortality rate 30–95% [1,4,5]. In Table 1 are presented diseases caused by some of the most often fungal pathogens among people.

Table 1. Fungal pathogens of humans and most often observed mycoses (based on [6,7]).

Superficial mycoses	• *Hortae werneckii* (Tinea nigra) • *Malassezia furfur* (Pityriasis versicolor) • *Piedraia hortae* (Black piedra) • *Trichosporon* spp. (White piedra)
Cutaneous and subcutaneous mycoses	• *Aspergillus* spp. (Onychomycosis, Keratitis) • *Candida* spp. (Tinea pedis, Tinea cruris, Onychomycosis, Keratitis) • *Chaetomium* spp. (Subcutaneous phaeohyphomycosis) • *Curvularia* spp. (Subcutaneous phaeohyphomycosis) • *Epidermophyton* spp. (Tinea pedis, Tinea cruris, Onychomycosis) • *Exophiala* spp. (Chromoblastomycosis, Subcutaneous phaeohyphomycosis) • *Fonsecaea* spp. (Chromoblastomycosis) • *Fusarium* spp. (Onychomycosis, Keratitis, Eumycotic mycetoma) • *Geotrichum* spp. (Onychomycosis) • *Microsporum* spp. (Tinea corporis, Tinea capitis) • *Phaeoacremonium* spp. (Eumycotic mycetoma) • *Phialophora* spp. (Chromoblastomycosis, Subcutaneous phaeohyphomycosis) • *Scopulariopsis brevicaulis* (Onychomycosis) • *Sporothrix schenckii* (Lymphocutaneous sporotrichosis) • *Trichophyton* spp. (Tinea pedis, Tinea corporis, Tinea cruris, Tinea capitis, Onychomycosis) • *Trichosporon* spp. (Onychomycosis)
Endemic mycoses	• *Blastomyces dermatitidis* (Blastomycosis) • *Histoplasma capsulatum* (Histoplasmosis) • *Coccidioides immitis/posadasii* (Coccidioidomycosis) • *Penicillium marneffei* (Penicilliosis) • *Paracoccidioides brasiliensis* (Paracoccidioidomycosis)
Opportunistic mycoses	• *Acremonium* spp. (Hyalohyphomycosis-cutaneous, disseminated infection) • *Alternaria* spp. (Phaeohyphomycosis-subcutaneous, sinusitis, disseminated infection) • *Aspergillus* spp. (Allergic reactions, Aspergillosis-nasal, sinusitis, bronchial, pulmonary, systemic dissemination) • *Bipolaris* spp. (Phaeohyphomycosis-subcutaneous, sinusitis, brain abscess) • *Candida* spp. (Candidiasis-superficial mucosal, cutaneous, widespread hematogenous distribution involving target organs) • *Cryptococcus* spp. (Cryptococcosis-cutaneous, pulmonary, meningitis) • *Curvularia* spp. (Phaeohyphomycosis-subcutaneous, sinusitis, disseminated infection) • *Fusarium* spp. (Hyalohyphomycosis-cutaneous, disseminated infection) • *Lichtheimia* spp. (Mucormycosis-cutaneous, invasive) • *Mucor* spp. (Mucormycosis-cutaneous, invasive) • *Paecilomyces* spp. (Hyalohyphomycosis-cutaneous, disseminated infection) • *Pneumocystis jirovecii* (Pneumocystosis-pneumonia, extrapulmonary manifestations) • *Rhizomucor* spp. (Mucormycosis-cutaneous, invasive) • *Rhizopus* spp. (Mucormycosis-cutaneous, invasive) • *Scedosporium* spp. (Hyalohyphomycosis-cutaneous, disseminated infection) • *Trichosporon* spp. (Trichosporonosis-invasive disease) • *Wangiella* spp. (Phaeohyphomycosis-subcutaneous, sinusitis, brain abscess)

The big problem is growing drug-resistance amid fungi. Among *Candida* and *Aspergillus* species is observed resistance to azoles, e.g., to fluconazole, voriconazole, and posaconazole. Some *Candida* species, especially *C. glabrata* and *C. parapsilosis*, can be echinocandin- and multidrug-resistant [8,9]. Acquired resistance to echinocandins has also been reported for yeasts *C. albicans*, *C. tropicalis*, *C. krusei*, *C. kefyr*, *C. lusitaniae*, and *C. dubliniensis* [10]. More than 3% of *Aspergillus fumigatus* isolates are resistant to one or more azoles [11]. Polyene resistance mainly concerns amphotericin B. Resistance to this drug is observed in *Fusarium* spp., *Trichosporon* spp., *Aspergillus* spp., and *Sporothrix schenckii* [12,13]. Resistance to amphotericin B has also been reported for *C. albicans*, *C. glabrata*, and *C. tropicalis* [14–16]. Cultures of some *Candida* species and *Cryptococcus neoformans* are presented in Figure 1.



Candida albicans ***C. krusei***

C. tropicalis ***Cryptococcus neoformans***

Figure 1. Cultures of selected yeast fungi on Sabouraud agar (Author of photos: Tomasz M. Karpiński).

The new epidemiological problem is *C. auris*, a multidrug-resistant organism first described in Japan in 2009 [17]. Recently, *C. auris* has been reported from 36 countries from six continents [18]. About 30% of isolates demonstrate reduced susceptibility to amphotericin B, and 5% can be resistant to the echinocandins [19,20]. The estimated mortality from *C. auris* fungemia range from 28% to 60% [21].

Fundamental issues are also the costs of treatment and hospitalization of patients with invasive fungal diseases. According to Drgona et al., all costs range from around €26,000 up to over €80,000 per patient [5].

Therefore, all time, new treatments for fungal infections are being sought. One option may be to apply natural products having antifungal activity. Among these, significant importances have essential oils, which can have a broad antimicrobial spectrum. Rich in the essential oils are among other plants from the Lamiaceae family.

In this review are presented antifungal activities of essential oils from seventy-two (72) plants of the Lamiaceae family. Moreover, are shown the most important compounds of these essential oils. For objective comparison of results, in this paper were included only antifungal studies specifying the minimum inhibitory concentrations (MICs) for essential oils. The MIC (expressed in µg/mL) is the lowest concentration of an antimicrobial agent in which no growth of a microorganism is observed in an agar or broth dilution susceptibility test [22–24].

2. Components of Essential Oils of Lamiaceae Family

The family Lamiaceae or Labiatae contains many valuable medicinal plants. In the family are 236 genera and between 6900 and 7200 species. To the most abundant genera belong *Salvia* (900 species), *Scutellaria* (360), *Stachys* (300), *Plectranthus* (300), *Hyptis* (280), *Teucrium* (250), *Vitex* (250), *Thymus* (220), and *Nepeta* (200). Lamiaceae plants rich in essential oils have great worth in natural medicine, pharmacology, cosmetology, and aromatherapy [25]. The essential oils are mostly present in leaves, however, they can be found in flowers, buds, fruits, seeds, rind, wood, or roots [26]. Essential oils are mixtures of volatile compounds, which are secondary plant metabolites. They play a role in the defense system of higher plants [27]. Essential oils may contain over 300 different compounds, mainly of molecular weight below 300 [28]. Some oils, e.g., obtained from *Lavandula*, *Geranium*, or *Rosmarinus,* contain 450 to 500 chemicals [29]. Among the active compounds of essential oils are various chemical classes, e.g., alcohols, ethers, aldehydes, ketones, esters, phenols, terpenes (monoterpenes, sesquiterpenes), and coumarins [30,31].

In Table 2 are presented the main chemical components of essential oils of selected Lamiaceae family plants. Plant names were unified according to The Plant List [32], however synonyms used in the literature were also left. Chemical component names were unified, according to PubChem [33].

Table 2. The main chemical components of the essential oils of selected Lamiaceae family plants.

Essential Oil	Main Chemical Components	References
Aeollanthus suaveolens Mart. ex Spreng. = *A. heliotropioides* Oliv.	Linalool (38.5%), α-Farnesene (25.1%), Massoialactone (4.5%), β-Caryophyllene (3.6%), Germacrene D (2.0%)	[34]
Agastache rugosa (Fisch. and C.A.Mey.) Kuntze	Methyl chavicol (93.45%), Methyl eugenol (2.48–50.51%), Estragole (8.55%), Eugenol (0.15–7.54%), Thymol (3.62%), Pulegone (2.56%), Limonene (2.49%), β-Caryophyllene (1.19–2.38%),	[35,36]
Ballota nigra subsp. *foetida* (Vis.) Hayek	β-Caryophyllene (21.8–22.6%), Caryophyllene oxide (18.0–20.5%), Germacrene D (13.1–16.5%), 2-Hexenal (6.5–11.2%), 1-Octen-3-ol (3.5–5.5%), β-Pinene (1.6–4.4%), Limonene (2.2–4.1%), Linalool (1.2–3.5%), β-Bourbonene (1.5–2.7%), α-Humulene (2.2–2.6%), α-Copaene (1.5–2.2%)	[37]
Clinopodium dalmaticum (Benth.) Bräuchler and Heubl = *Micromeria dalmatica* Benth.	Piperitenone oxide (41.77%), Pulegone (15.94%), Piperitenone (10.19%), Limonene (5.77%), Piperitone (3.39%), α-Pinene (2.9%), β-Pinene (2.16%),	[38]
Clinopodium nepeta subsp. *glandulosum* (Req.) Govaerts = *Calamintha glandulosa* (Req.) Bentham = *Calamintha officinalis* Moench	Piperitenone (trace–42.6%), Piperitone (0.0–40.3%), Carvone (1–38.7%), Pulegone (0.6–9.7%), Shisofuran (0.1–9.7%), Menthone (trace–8.3%), Dihydrocarveol acetate (0.1–7.6%), Dihydrocarveol (0–6.9%),1,8-Cineole (0.0–6.4%), cis-Carvyl acetate (0.0–6.1%),	[39,40]
Clinopodium nepeta (L.) Kuntze = *Calamintha nepeta* (L.) Savi	Pulegone (2.4–84.7%), Isomenthone (1.9–51.3%), Menthone (0.0–35.4%), Crysanthenone (1.3–33.9%), 1,8-Cineole (0.3–21.4%), Piperitenone oxide (0.0–19.1%), Limonene (0.0–13.6%), Isopulegone (0.0–9.4%), Piperitenone (0.0–7.7%), Cinerolone (0.0–5.8%), Isopulegol (0.0–4.1%), Isomenthol (0.0–3.9%), β-Caryophyllene (0.0–3.8%), 3-Octanol (0.0–3.0%), β-Pinene (0.0–2.3%), cis-Piperitone oxide (0.0–2.2%)	[41,42]

Table 2. *Cont.*

Essential Oil	Main Chemical Components	References
Clinopodium thymifolium (Scop.) Kuntze = *Micromeria thymifolia* (Scop.) Fritsch	Pulegone (32.81%), Piperitenone (25.7%), Piperitone (11.71%), Isomenthone (4.98%), Limonene (2.4%), β-Caryophyllene (2.39%)	[38]
Clinopodium umbrosum (M.Bieb.) Kuntze = *Calamintha umbrosa* Benth.	β-Caryophyllene (13.9%), Germacrene D (11.6%), Spathulenol (10.6%)	[43]
Dracocephalum heterophyllum Benth.	Citronellol (74.2%), Geraniol (2.8%), cis-Rose oxide (2.2%), Citronellyl acetate (1.7%)	[44]
Hymenocrater longiflorus Benth.	δ-Cadinol (18.49%), α-Pinene (10.16%), p-Menth-1-en-8-ol (9.82%), Hedycaryol (6.42%), β-Eudesmol (4.56%), Spathulenol (4.14%), δ-Cadenene (3.02%), Linalool (2.98%), Caryophyllene oxide (2.81%), β-Bourbonene (2.72%), β-Caryophyllene (2.29%)	[45]
Hyptis ovalifolia Benth.	(R)-6-[(Z)-1-Heptenyl]-5,6-dihydro-2H-pyran-2-one (60.0%), γ-Cadinene (6.6%), Viridiflorol (6.08%), Caryophyllene oxide (4.98%), γ-Elemene (4.38%)	[46]
Hyssopus officinalis L.	Pinocamphone (5.78–50.77%), 1,8-Cineole (0.47–36.43%), Pinocarvone (0.44–23.4%), β-Pinene (13.38–19.55%), Isopinocamphone (15.32%), α-Phellandrene (trace–3.74%), Sabinene (1.7–2.9%), Myrtenol (1.39–2.7%), α-Pinene (1.01–2.57%), cis-Sabinene hydrate (0.0–2.5%), Myrtenyl methyl ether (1.64–2.1%)	[44,47,48]
Lavandula angustifolia Mill.	Linalool (20.18–45.8%), Linalyl acetate (4.6–43.13%), Lavandulyl acetate (0–16.01%), 1,8-Cineole (0.6–13.1%), Camphor (0.52–11.2%), Borneol (0.76–7.5%), Terpinen-4-ol (1.05–5.8%), β-Caryophyllene (0.6–4.95%), Lavandulol (0–3.09%), β-Ocimene (1.5–2.84%), Myrcene (0.4–2.41%)	[49–51]
Lavandula multifida L.	Carvacrol (41.5–42.8%), β-Ocimene (27.0–27.4%), Myrcene (5.5–5.7%), β-Bisabolene (5.0–5.6%), Terpinolene (2.1–3.1%), α-Farnesene (2.6–2.8%)	[52]
Lavandula pedunculata (Mill.) Cav.	Fenchone (6.2–44.5%), 1,8-Cineole (5.1–34.3%), Camphor (8.7–34.0%), β-Pinene (1.4–9.0%), α-Pinene (2.5–8.0%), Camphene (0.8–6.1%), Linalool (0.5–3.8%), Bornyl acetate (0.9–3.5%), Borneol (0.6–3.4%), α-Cadinol (0.2–3.1%), cis-Verbenol (0.2–2.8%), Myrtenal (0.8–2.4%), trans-Verbenol (1.1–2.0%)	[53]
Lavandula stoechas L.	Fenchone (0.0–36.2%), 1,8-Cineole (0–33.9%), Camphor (2.2–18%), α-trans-Necrodyl acetate (0.0–17.4%), Lavandulyl acetate (0.0–7.6%), α-trans-Necrodol (0.0–7.1%), Linalool (0.0–6.2%), α-Copaene-8-ol (0.7–4.7%), Viridiflorol (1.4–3.6%), α-Pinene (1.1–3.2%), 2,3,4,4-Tetramethyl-5-methylene-cyclopenten-1-one (0.0–2.8%), Lyratyl acetate (0–2.4%), Myrtenyl acetate (1.0–2.0%), 1,1,2,3-Tetramethyl-4-hidroximethyl-2-cyclopentene (0.0–2.0%)	[51,54]
Lavandula viridis L'Her.	1,8-Cineole (34.5–42.2%), Camphor (13.4%), α-Pinene (9.0%), Linalool (6.7–7.9%)	[55]
Lepechinia mutica (Benth.) Epling	Δ^3-Carene (8.69–24.23%), Thujopsan-2-α-ol (0.0–11.9%), Shyobunol (0.0–10.8%), β-Pinene (3.78–7.96%), δ-Cadinene (0.0–6.96%), Globulol (0.0–5.91%), Valerianol (0.0–5.19%), epi-Cubebol (0.0–4.62%), β-Caryophyllene (0.0–4.55%), Limonene (3.79–4.47%), α-Eudesmol (0.0–4.47%), α-Phellandrene (0.34–3.8%), β-Phellandrene (3.79%), γ-Cadinene (0.0–2.86%), α-Pinene (1.23–2.68%), o-Cymene (0.0–2.04%), Isobornyl acetate (0.0–2.2%)	[56,57]

Table 2. *Cont.*

Essential Oil	Main Chemical Components	References
Marrubium vulgare L.	γ-Eudesmol (11.93%), β-Citronellol (9.9%), Citronellyl formate (9.5%), Germacrene-D (9.37%), Geranyl formate (6.25%), Geranyl tiglate (5.53%), Ledene (5.35%), 1,8-Cineole (3.72%), Neryl acetate (3.41%), δ-Cadinene (3.3%), Cyclononasiloxane octadecamethyl (3.08%), Geraniol (2.74%), N-trimethylsilyl trifluoroacetamide (2.35%), Eicosamethylcyclodecasiloxane (2.29%), α-Thujone (2.29%), trans-Caryophyllene (2.15%)	[58]
Melissa officinalis L.	Geranial (23.4%), Neral (16.5%), Citronellal (13.7%), β-Caryophyllene (4.6%), Geraniol (3.4%), Isomenthone (3.0%), Menthol (2.9%), Methyl citronellate (2.7%), Germacrene D (2.4%), Limonene (2.2%)	[59]
Mentha cervina L.	Isomenthone (8.7–77%), Pulegone (12.9–75.1%), Menthone (0.8–4.4%), Limonene (0.8–4.3%)	[60]
Mentha × *piperita* L.	Menthol (34.82–43.85%), Menthone (9.1–31.68%), Carvone (0.0–19.54%), Menthyl acetate (1.64–17.4%), Anethole (0.0–9.54%), Isomenthone (4.71–8.08%), Limonene (0.86–6.9%), Menthofuran (6.8%), Eucalyptol (4.36–6.21%), 1,8-Cineole (5.6%), Pulegone (0.47–5.15%), Isomenthol acetate (4.56–4.91%), Isomenthol (0.68–3.58%), Sabinene (0.0–2.5%)	[61–64]
Mentha pulegium L.	Pulegone (2.3–70.66%), Piperitone (0.24–38.0%), Piperitenone (1.58–33.0%), Neomenthol (11.21%), α-Terpineol (0.0–4.7%), 1,8-Cineole (0.11–4.0%), Piperitenone oxide (0.0–3.4%), Menthone (2.63–3.0%), Borneol (0.0–2.9%), Isopulegone (2.33%)	[65,66]
Mentha requienii Benth.	Pulegone (77.6%), Isomenthone (18.2%), Limonene (1.76%)	[67]
Mentha spicata L.	Pulegone (0.0–78.7%), Carvone (0.0–59.12%), Menthol (0.0–39%), Menthone (5.1–21.9%), Neomenthol (11.2%), Menthyl acetate (0.0–6.9%), Dihydrocarveol (0.0–6.27%), Limonene (1.0–5.8%), 1,8-Cineole (3.0–5.42%), cis-Dihydrocarvone (0.0–4.9%), cis-Carveol (0.0–3.9%), β-Caryophyllene (0.7–2.8%), β-Myrcene (0.3–2.3%)	[49,51,61,68]
Mentha suaveolens Ehrh.	Piperitenone oxide (0.0–87.25%), Carvone (0.0–50.59%), Pulegone (0.0–50.0%), Demelverine (0.0–43.46%), Cinerolone (0.0–38.79%), p-Cymenene (0.0–35.22%), Limonene (0.0–31.25%), Piperitone oxide (0.0–26.0%), p-Cymenol-8 (0.0–20.6%), Spathulenol (0.0–18.35%), β-Caryophyllene oxide (0.3–17.25%), α-Pharnesene (0.0–16.54%), α-Cadinol (0.09–10.69%), Calamenene (0.44–10.63%), α-Cubenene (0.0–10.08%), α-Caryophyllene (2.0–9.8%), Veridiflorol (0.0–7.59%), Cubenol (0.0–7.46%), Verbenone (0.0–6.56%), δ-Fenchol (0.3–5.9%), Menthone (0.0–5.7%), Borneol (0.12–5.6%), Citronellyl acetate (0.0–5.45%), δ-Cadinene (0.0–4.89), Eucalyptol (0.0–4.21%), cis-8-Menthene (0.3–4.2%), Fenchone (0.1–3.6%), Geraniol (1.0–3.4%), τ-Muurolol (0.0–3.29%), α-Pinene (0.1–2.7%), β-Caryophyllene (2.56%), cis-Carveol (2.31%), Germacrene D (0.0–2.04%)	[69–71]
Micromeria albanica (K. Maly) Silic	Piperitenone oxide (38.73%), Pulegone (13.43%), Piperitenone (9.72%), Piperitone (5.62%), Limonene (3.2%), α-Copaene (2.12%)	[38]

Table 2. *Cont.*

Essential Oil	Main Chemical Components	References
Moluccella spinosa L.	α-Pinene (26.6%), Caryophyllene oxide (16.8%), β-Caryophyllene (8.6%), α-Thujene (5.9%), Nonacosane (5.5%), Heptacosane (5.3%), Ethylbenzaldehyde (3.4%), Pentacosane (2.5%), Tetracosane (2.3%), Sabinene (2.2%)	[72]
Nepeta ciliaris Benth. = *Nepeta leucophylla* Benth.	Caryophyllene oxide (14.8–26.3%), β-Caryophyllene (18.0%), β-Sesquiphellandrene (15.0%), Iridodial b-monoenol acetate (9.8%)	[43]
Nepeta clarkei Hook. f.	β-Sesquiphellandrene (22.0%), Actinidine (10.0%), Germacrene D (8.0%)	[43]
Ocimum basilicum L.	Linalool (18.0–68.0%), Methyl chavicol (0.0–57.3%), Geraniol (0.0–16.5%), 1,8-Cineole (1.4–15.1%), p-Allylanisole (0.2–13.8%), Eugenol (0.0–12.32%), Limonene (0.2–10.4%), β-Farnesene (0.0–6.3%), τ-Cadinol (trace–5.8%), β-Caryophyllene (0.0–4.5%), α-Bergamotene (0.0–4.34%), α-Cadinol (0.0–4.05%), β-Elemene (0.0–3.62%), δ-Cadinene (0.0–3.6%), Germacrene D (0.0–3.5%), γ-Cadinene (0.0–2.8%), Camphor (0.0–2.4%), β-Myrcene (0.2–2.3%), Terpinen-4-ol (0.0–2.2%), Guaiene (0.0–2.1%), Estragole (0.0–2.03%), Isolimonene (0.0–2.0%), α-Bulnesene (0.0–2.0%), γ-Terpinene (0.0–2.0%)	[64,68,73–76]
Ocimum × *africanum* Lour. = *Ocimum* × *citriodorum*	Nerol (23.0%), Geranial (15.77%), Methyl chavicol (9.45%), Linalool (9.42%), β-Bisabolenene (8.31%), β-Caryophyllene (7.8%), Geraniol (5.2%), Neral (4.93%), α-Bergamotene (3.52%), α-Bisabolene (2.29%), β-Cubebene (2.26%)	[76]
Ocimum campechianum Mill. = *Ocimum micranthum* Willd.	Eugenol (46.55%), β-Caryophyllene (11.94%), β-Elemene (9.06%), 1,8-Cineole (5.35%), δ-Elemene (4.17%), Bicyclogermacrene (2.9%), cis-Ocimene (2.69%), allo-Ocimene (2.42%), α-Humulene (2.4%)	[73]
Ocimum forskolei Benth.	endo-Fenchol (31.1%), τ-Cadinol (12.2%), Fenchone (12.2%), Camphor (6.2%), Linalool (5.7%), Methyl(E)-cinnamate (5.1%), α-Bergamotene (3.1%), γ-Cadinene (2.9%), endo-Fenchyl acetate (2.8%), Limonene (2.5%)	[77]
Ocimum gratissimum L.	Eugenol (7.42–57.82%), Ethyl cinnamate (0.0–34.0%), Linalool (30.0–32.95%), 1,8-Cineole (6.5–21.91%), α-Bisabolene (0.0–17.19%), Camphor (3.8–11.97%), Thymol (0.0–9.8%), α-Cadinol (5.18%), Germacrene D (0.79–4.76%), α-Terpineol (3.36%), γ-Terpinene (0.0–3.06%), β-Caryophyllene (1.68–3.03%), p-Cymene (0.0–2.11%)	[78–80]
Ocimum tenuiflorum L. = *Ocimum sanctum* L.	Eugenol (0.0–61.3%), Methyl chavicol (0.0–44.63%), Linalool (0.26–21.84%), α-Caryophyllene (3.3–11.89%), Germacrene D (0.37–9.14%), Carvone (0.0–6.31%), Limonene (0.71–4.39%), β-Caryophyllene (1.4–3.3%), α-Cubebene (0.0–2.54%), Carvacrol (0.0–2.04%)	[81–83]
Origanum compactum Benth.	Carvacrol (43.26%), Thymol (21.64%), p-Cymene (13.95%), γ-Terpinene (11.28%)	[84]
Origanum majorana L.	Terpinen-4-ol (6.66–33.84%), Sabinene hydrate (2.31–28.33%), 1,8-Cineole (0.0–20.9%), Carvacrol (0.0–20.8%), γ-Terpinene (7.59–19.5%), Thymol (0.0–12.18%), α-Terpinene (3.03–10.08%), β-Phellandrene (1.96–8.0%), p-Cymene (2.45–7.84%), Sabinene (3.2–6.7%), Limonene (0.0–5.3%), α-Terpineol (2.7–4.7%), Linalool (0.0–4.4%), Terpinolene (0.98–3.76%), Linalool acetate (1.82–3.2%), Geraniol (2.7%), β-Caryophyllene (1.7–2.38%), α-Pinene (0.0–2.0%)	[62,68,85–87]

Table 2. *Cont.*

Essential Oil	Main Chemical Components	References
Origanum vulgare L.	Pulegone (0.0–77.45%), Carvacrol (0.21–65.9%), Cymenol (0.0–58.6%), Thymol (3.7–45.22%), o-Cymene (0.0–14.33%), Terpinen-4-ol (0.03–12.55%), β-Terpineol (0.0–10.46%), p-Cymene (0.5–9.3%), γ-Terpinene (3.1–9.12%), Borneol (0.0–6.1%), α-Pinene (0.0–5.1%), Menthone (0.0–4.86%), Linalool (0.0–4.8%), β-Bisabolene (0.0–4.5%), Caryophyllene oxide (0.0–4.5%), Sabinene (0.0–3.91%), β-Phellandrene (0.0–3.74%), β-Caryophyllene (00–3.7%), α-Terpineol (0.0–3.35%), Sabinene hydrate (0.0–3.31%), α-Cadinol (0.0–3.3%), α-Terpinene (1.63–3.1%), Eucalyptol (0.0–2.8%), β-Ocimene (0.0–2.77%), cis-Isopulegone (2.22%), β-Myrcene (0.0–2.2%), Anisole (0.0–2.13%), Piperitenone (0.0–2.13%), Germacrene D (0.0–1.23%)	[49,62,64,68,74, 88–91]
Pogostemon cablin (Blanco) Benth.	Patchouli alcohol (38.3–44.52%), α-Bulnesene (0.0–13.3%), δ-Guaiene (12.64%), α-Guaiene (8.89–9.6%), Pogostol (0.0–6.2%), Seychellene (5.8%), α-Bergamotene (5.76%), Eremophilene (4.34%), β-Guaiene (3.54%), β-Caryophyllene (1.93–3.0%), β-Patchoulene (1.8–2.77%)	[92,93]
Pogostemon heyneanus Benth.	Acetophenone (51.0%), Patchouli alcohol (14.0%), Nerolidol (5.4%), β-Pinene (5.3%), Limonene (4.0%), Benzoyl acetone (3.1%), α-Pinene (2.4%), β-Caryophyllene (2.0%)	[93]
Premna microphylla Turcz.	Blumenol C (49.7%), β-Cedrene (6.1%), Limonene (3.8%), α-Guaiene (3.3%), Cryptone (3.1%), α-Cyperone (2.7%), cis-14-nor-Muurol-5-en-4-one (2.4%)	[94]
Rosmarinus officinalis L.	α-Pinene (5.4–37.9%), 1,8-Cineole (0.88–26.54%), Eucalyptol (0.0–24.34%), Limonene (0.0–21.7%), Camphor (2.45–21.6%), Myrcene (0.9–20.18%), Borneol (0.0–18.08%), Bornyl acetete (0.92–14.9%), Verbenone (1.36–12.0%)Camphene (1.7–11.38%), Linalool oxide (0.0–10.8%), β-Pinene (0.0–6.95%), β-Caryophyllene (0.0–6.3%), Linalool (00–5.32%), o-Cymene (0.0–4.43%), p-Cymene (0.0–4.34%), β-Phellandrene (0.0–3.9%), Sabinene (0.0–3.72%), α-Terpineol (1.19–3.36%), Isobornyl acetate (0.0–3.3%), Carvacrol (0.0–3.15%), Verbenol (0.7–3.03%), α-Humulene (0.0–2.6%), α-Terpinene (0.21–2.4%), Terpinen-4-ol (0.34–2.15%)	[51,62,68,87,91, 95–98]
Salvia fruticosa Miller	1,8-Cineole (16.9–54.4%), Camphor (0.6–18.34%), Manool (0–11.2%), β-Thujone (0.6–9.0%), β-Pinene (0.0–9.0%), Sabinene (0.0–8.6%), Viridiflorol (0.0–8.4%)β-Caryophyllene (1.53–8.3%), α-Thujone (trace–8.1%), Borneol (0.0–8.0%), Camphene (0.0–7.0%), α-Pinene (1.5–6.85%), Bornyl acetate (0.0–6.8%), α-Terpineol (trace–6.7%), Myrcene (1.3–5.2%), Caryophyllene oxide (0.0–3.9%), α-Terpinyl acetate (0.0–2.2%), α-Humulene (0.16–1.5%)	[49,51,99]
Salvia mirzayanii Rech. f. and Esfand	1,8-Cineole (41.2%), Linalool acetate (10.7%), α-Terpinyl acetate (5.7%), Myrcene (4.7%), Geranyl acetate (3.7%), γ-Cadinene (3.3%), Linalool (2.5%), Neryl acetate (2.3%)	[100]

Table 2. *Cont.*

Essential Oil	Main Chemical Components	References
Salvia officinalis L.	1,8-Cineole (4.2–50.3%), Camphor (8.8–25.0%), α-Thujone (1.2–19.9%), Viridiflorol (0.5–17.5%), β-Thujone (0.1–9.9%), β-Pinene (0.8–7.3%), β-Caryophyllene (1.4–5.5%), Borneol (1.5–5.4%), α-Pinene (0.5–4.8%), Camphene (0.2–3.9%), Bornyl acetate (0.2–3.3%), α-Terpineol (0.0–3.1%), α-Terpenyl acetate (1.4–2.9%), α-Humulene (0.4–2.6%),α-Farnesene (0.0–2.5%), Eicosane (0.0–2.0%)	[96,101]
Salvia sclarea L.	Linalyl acetate (84%), Caryophyllene oxide (24.1%), Linalool (13.6%), 1H-Naphtho(2,1,6)pyran (8.6%), Sclareol (11.5%), Spathulenol (11.4%), β-Caryophyllene (5.1%)	[85,102]
Satureja hortensis L.	Thymol (23.12–29.0%), Carvacrol (24.5–26.5%), γ-Terpinene (20.72–22.6%), p-Cymene (6.3–9.3%), α-Terpinene (2.2–2.93%), α-Pinene (2.6–2.91%), β-Pinene (0.92–2.7%), Limonene (0.0–2.55%), β-Bisabolene (0.2–2.2%)	[103,104]
Satureja montana L.	Carvacrol (47.1%), p-Cymene (9.0%), γ-Terpinene (6.1%), β-Caryophyllene (3.6%), Linalool (3.1%), Thymol (2.6%), Borneol (2.1%)	[68]
Satureja thymbra L.	Thymol (25.16–44.5%), γ-Terpinene (11.1–39.23%), p-Cymene (7.17–21.7%), Carvacrol (4.18–5.3%), Carvacrol methyl ether (0.1–3.33%), α-Terpinene (1.0–3.26%), β-Caryophyllene (1.2–2.76%), Caryophyllene oxide (0.32–2.0%)	[51,105]
Stachys cretica L.	Germacrene D (12.9–20.3%), β-Caryophyllene (0.9–9.5%), α-Pinene (0.7–8.6%), Octacosane (0.0–7.2%), β-Pinene (1.5–6.2%), Linalyl acetate (0.0–5.2%), Nonacosane (0.4–4.9%), 9-Geranyl-p-cymene (0.0–4.9%), Heptacosane (0.3–4.8%), cis-Chrysanthenyl acetate (0.0–4.8%), β-Farnesene (3.1–4.0%), Hexadecanoic acid (1.3–3.5%), Caryophyllene oxide (0.5–2.9%), β-Bisabolene (1.6–2.8%), Linalool (0.0–2.6%), Pentacosane (0.0–2.5%), Sesquisabinene (2.1%), Geranyl acetate (0.0–2.1%)	[106]
Stachys officinalis (L.) Trevis	Germacrene D (19.9%), β-Caryophyllene (14.1%), α-Humulene (7.5%), δ-Cadinene (4.0%), β-Bourbonene (3.8%), α-Selinene (3.4%), γ-Muurolene (3.2%), Oct-1-en-3-ol (2.9%), Caryophyllene oxide (2.5%), Hexadecanoic acid (2.4%), β-Selinene (2.1%), γ-Cadinene (2.0%), τ-Muurolol (2.0%)	[107]
Stachys pubescens Ten.	Germacrene (22.4%), δ-Cadinene (19.7%), 2,6-Octadien (11.5%), Linalool (9.7%), Limonene (6.3%), δ-Elemene (5.4%), β-Ocimene (2.8%), α-Terpinene (2.7%), 2,6-Octadienal (2.1%)	[108]
Teucrium sauvagei Le Houerou	β-Eudesmol (28.8%), τ-Cadinol (17.5%), α-Thujene (8.7%), γ-Cadinene (5.6%), Sabinene (4.8%), β-Selinene (4.2%), Limonene (2.8%), γ-Selinene (2.8%), α-Selinene (2.8%), δ-Cadinene (2.2%), Terpinen-4-ol (2.2%), p-Cymene (2.0%),	[109]
Teucrium yemense Deflers.	Caryophyllene oxide (4.3–20.1%), 7-epi-α-Selinene (1.3–20.1%), β-Caryophyllene (11.2–19.1%), α-Cadinol (2.0–9.5%), α-Pinene (2.3–6.6%), δ-Cadinene (0.4–6.5%), α-Humulene (4.0–6.4%), τ-Cadinol (2.0–5.7%), γ-Selinene (0.4–5.5%), τ-Muurolol (0.6–4.9%), Shyobunol (0.0–4.6%), Valencene (0.0–3.7%), Ledol (0.5–3.6%), cis-Sesquisabinene hydrate (0.9–3.4%), β-Pinene (1.1–3.1%), Germacrene D-4-ol (0.0–3.1%), γ-Cadinene (0.0–2.7%), β-Selinene (0.3–2.5%), Alloaromadendrene (trace–2.2%)	[77]

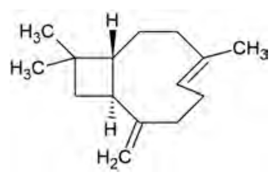
Table 2. *Cont.*

Essential Oil	Main Chemical Components	References
Thymbra capitata (L.) Cav. = *Thymus capitatus* (L.) Hoffmanns. and Link = *Coridothymus capitatus* (L.) Rchb.f. Solms	Carvacrol (35.6–75.0%), Thymol (0.1–29.3%), p-Cymene (5.0–21.0%), γ-Terpinene (4.0–12.3%), α-Terpinene (1.0–3.0%), β-Myrcene (0.8–3.0%), Linalool (0.5–2.9%), β-Caryophyllene (0.2–2.5%)	[51,110–112]
Thymbra spicata L.	Carvacrol (20.1–64.0%), γ-Terpinene (11.6–31.2%), p-Cymene (9.6–26.0%), α-Terpinene (1.2–10.1%), β-Myrcene (0.9–7.7%), Thujene (trace–5.2%), β-Caryophyllene (0.5–5.1%)	[51,113,114]
Thymus bovei Benth.	Geraniol (35.38%), α-Citral (20.37%), β-Citral (14.76%), Nerol (7.38%), 3-Octanol (4.38%)	[115]
Thymus daenensis Celak.	Carvacrol (31.46%), α-Terpineol (22.95%), Thymol (20.2%), Camphene (6.27%), 2,6-Octadien (2.22%), Borneol (2.17%), Cyclohexanone (2.1%)	[108]
Thymus kotschyanus Boiss. and Hohen.	Thymol (46.72%), Benzene (6.88%), Carvacrol (3.73%), γ-Terpinene (3.58%), β-Caryophyllene (3.39%), Linalool (2.88%), Phenol (2.61%), Borneol (2.51%), Isopropyl (2.07%)	[108]
Thymus mastichina (L.) L.	1,8-Cineole (67.4%), Linalool (4.3%), β-Pinene (4.0%), α-Terpineol (3.5%), α-Pinene (3.0%), Sabinene (2.4%)	[116]
Thymus migricus Klokov et Des.-Shost.	Thymol (44.9%), Geraniol (10.8%), γ-Terpinene (10.3%), Citronellol (8.5%), p-Cymene (7.2%)	[117,118]
Thymus pulegioides L.	Thymol (26.0%), Carvacrol (21.0%), γ-Terpinene (8.8%), p-Cymene (7.8%), Octan-3-one (3.9%), Camphor (3.9%), β-Bisabolene (3.0%), Borneol (2.9%), Oct-1-en-3-ol (2.0%)	[119]
Thymus schimperi Ronniger	Carvacrol (13.91–39.07%), Thymol (11.53–34.66%), o-Cymene (18.72–27.06%), γ-Terpinene (4.13–13.73%), Linalool (3.34–3.59%), 3-Octanone (1.05–2.67%), α-Terpinene (1.67–2.37%)	[120]
Thymus serpyllum L.	Thymol (52.6%), p-Cymene (15.3%), β-Caryophyllene (6.8%), Sabinene hydrate (3.8%), γ-Terpinene (2.9%), Terpinen-4-ol (2.4%)	[68]
Thymus striatus Vahl.	Thymol (59.5%), γ-Terpinene (11.6%), p-Cymene (6.4%), Carvacrol methyl ether (5.9%), Carvacrol (4.9%), α-Terpinene (3.3%), β-Caryophyllene (2.3%)	[121]
Thymus vulgaris L.	Carvacrol (3.5–70.3%), Thymol (0.6–51.8%), Borneol (0.0–40.6%), p-Cymene (2.9–38.9%), o-Cymene (0.0–31.7%), α-Terpineol (0.0–19.9%), Linalool (0.0–16.0%), γ-Terpinene (0.3–12.65%), Camphene (0.0–12.3%), 1,8-Cineole (0.0–11.3%), α-Pinene (0.2–6.1%), β-Caryophyllene (0.0–3.5%), Neomenthol (0.0–2.8%), β-Cubebene (0.0–2.4%), Geraniol (0.0–2.32%), Menthone (0.0–2.2%)	[61,64,74,85,87,104,116,122–126]
Thymus zygis L.	Linalool (5.5–39.7%), Thymol (0.52–39.6%), p-Cymene (2.2–21.2%), Terpinen-4-ol (1.0–11.7%), β-Myrcene (3.0–8.6%), γ-Terpinene (7.6–7.9%), α-Terpinene (1.2–4.2%), β-Caryophyllene (1.6–3.6%), α-Pinene (0.9–3.6%), Limonene (1.7–2.6%), Carvacrol (0.08–2.4%), Terpinolene (0.2–2.0%)	[116,127]
Vitex agnus-castus L.	Eucalyptol (20.5%), 1,8-Cineole (1.5–19.61%), Bicyclogermacrene (0.0–16.2%), β-Farnesene (0.0–16.1%), Sabinene (0.0–14.57%), Sclarene (0.0–10.9%), α-Pinene (0.9–9.76%), Manool (0.0–8.2%), β-Caryophyllene (3.0–6.6%), β-Caryophyllene oxide (0.0–5.83%), Limonene (0.0–4.89%), Vulgarol B (0.0–4.7%), β-Pinene (0.4–4.4%), α-Terpinyl acetate (1.2–4.21%), β-Sitosterol (3.13%), p-Cymene (0.0–3.11%), Geranyl linalool (0.0–3.1%), β-Phellandrene (0.0–3.0%), Cembrene A (0.7–2.8%), Beyrene (0.0–2.6%), β-Myrcene (trace–2.12%), γ-Elemene (2.11%), s-Cadinol (2.01%)	[51,128,129]

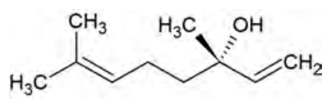
Table 2. *Cont.*

Essential Oil	Main Chemical Components	References
Zataria multiflora Boiss.	Thymol (25.8–48.4%), Carvacrol (1.5–34.36%), Carvacrol methyl ether (0.0–28.32%), p-Cymene (2.27–13.2%), γ-Terpinene (0.92–10.6%), Linalool (0.9–6.52%), α-Terpinenyl acetate (5.4%), α-Terpineol (0.5–3.69%), α-Pinene (0.02–3.13%), β-Caryophyllene (2.24–3.12%), Carvacrol acetate (0.0–2.26%), Terpinen-4-ol (0.0–2.21%)	[117,130]
Ziziphora clinopodioides L.	Carvacrol (0.63–74.29%), Thymol (7.28–55.6%), γ-Terpinene (1.54–24.56%), p-Cymene (2.21–10.25%), α-Terpinene (0.39–2.77%)	[131,132]
Ziziphora tenuior L.	Pulegone (46.8%), p-Menth-3-en-8-ol (12.5%), Isomenthone (6.6%), 8-Hydroxymenthone (6.2%), Isomenthol (4.7%), Limonene (3.2%)	[133]

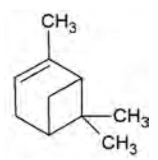
To the chemical components most commonly found as the main ingredients in essential oils, among plants presented in Table 2, include β-caryophyllene (41 plants), linalool (27 plants), limonene (26), β-pinene (25), 1,8-cineole (22), carvacrol (21), α-pinene (21), p-cymene (20), γ-terpinene (20), and thymol (20) (Figure 2). Sesquiterpene β-caryophyllene seems particularly important antifungal component in the Lamiaceae family. Its activity and its derivatives, such as caryophyllene oxide is well known [134–136]. According to Bona et al. [137], essential oils containing high concentrations of phenolic monoterpenes (e.g., carvacrol, p-cymene, thymol) have great antifungal activities. Rich in these substances are, among others *Origanum* and *Thymus* plants. Important antifungal chemicals often presented in Lamiaceae are also other monoterpenes as alcohol linalool and cyclic 1,8-cineole, limonene, pinenes, and terpinenes [138–146]. Table 1 shows that all of these antifungal substances are common in presented plants.



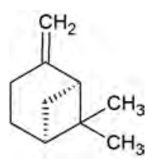
β-caryophyllene



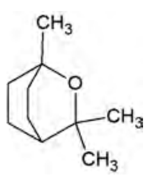
linalool



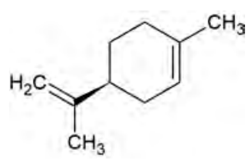
α-pinene



β-pinene

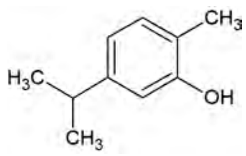


1,8-cineole

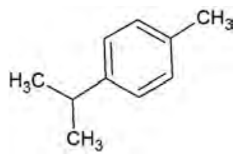


limonene

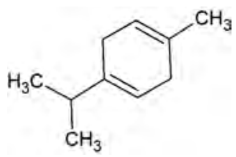
Figure 2. *Cont.*



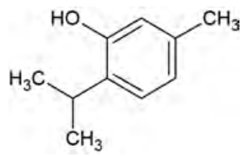
carvacrol



p-cymene



γ-terpinene



thymol

Figure 2. Chemical formulas of ten substances the most commonly found in essential oils of Lamiaceae plants presented in Table 1.

3. Antifungal Activity of Essential Oils of Lamiaceae Family

In Table 3 are shown the antifungal activities of selected Lamiaceae essential oils. More than half of the essential oils have good activity (<1000 µg/mL) against fungi. In some cases are observed significant discrepancies between different studies. An example could be the action of essential oils from Italian *Calamintha nepeta* against *Candida albicans*. In the work of Marongiu et al. [39], minimal inhibitory concentrations amounted to 1.25–2.5 µg/mL, while in Božović et al. [40] MICs were between 780 to 12,480 µg/mL. Differences may be related to the different biochemical composition of the examined essential oils. In results presented by Marongiu et al. [39] the main components of essential oils were pulegone (39.9–64.4%), piperitenone oxide (2.5–19.1%) and piperitenone (6.4–7.7%), while in Božović et al. [40] three main substances were pulegone (37.7–84.7%), crysanthenone (1.3–33.9%) and menthone (0.5–35.4%). Some authors have described that the content of active substances varies depending on the season. In studies of Gonçalves et al. [60] in *Mentha cervina* during the flowering phase in August amount of isomenthone and pulegone in essential oil amounted 8.7% and 75.1% respectively. Simultaneously, in the vegetative phase in February, the content of both components changed significantly and amounted to 77.0% for isomenthone and 12.9% for pulegone. Similarly, Al-Maskri et al. [75] presented essential changes in some compounds of *Ocimum basilicum* essential oil between winter and summer. In the summer essential oil, there is significantly more of linalool, p-allylanisole and β-farnesene, and at the same time much less content of limonene and 1,8-cineole. In this work, a seasonal variation of chemical composition is directly related to other antifungal activities. It is particularly evident in action against *Aspergillus niger*, which was lower in the summer season. Zone of growth inhibition (ZOI) for winter essential oil was 21 mm and MIC > 50 µg/mL, while for summer essential oil-ZOI was 13 mm and MIC > 100 µg/mL [75]. Influence on the content of chemical substances in essential oils also has a method of obtaining them. Ćavar et al. [40] compared the composition of oils obtained from *Calamintha glandulosa* using three methods: Hydrodistillation (HD), steam distillation (SD) and aqueous reflux extraction (ARE). For example, the level of menthone was 3.3% in ARE, 4.7% in HD, and 8.3% in SD method, while for shisofuran was only 0.1% in HD and SD, and even 9.7% in ARE [40]. Additionally, many other factors can affect antimicrobial activity, such as amount and concentration of inoculum, type of culture medium, pH of the medium and incubation time. All these factors can affect the value of MIC [145]. Differences are visible in Table 2. Generally, it can be assumed that the best activity (MICs < 100) have essential oils from *Clinopodium* spp. (excluding *C. nepeta* subsp. *glandulosum* and *C. umbrosum*), *Lavandula* spp., *Mentha* spp. (excluding *M. piperita*), *Thymbra* spp., and *Thymus* spp. (excluding *T. migricus* and *T. vulgaris*). The highest values of MICs are presented among others for *Aeollanthus suaveolens*, *Agastache rugosa*, *Lepechinia mutica*, *Mentha* × *piperita*, and *Salvia sclarea*. Simultaneously, some essential oils have a very different activity, and MIC values differ depending on the region, chemical composition, research methodology, etc. Significant variations can be observed even in *Ocimum basilicum* (MICs 1–10,000), *O. sanctum* (MICs 0.1–500), *Origanum majorana* (MICs 0.5–14,400) or in *Thymus vulgaris* (MICs 0.08–3600).

The mode of action of essential oils is multidirectional. Essential oils lead to disruption of the cell wall and cell membrane through a permeabilization process. The lipophilic compounds of essential oils can pass through the cell wall and damage polysaccharides, fatty acids, and phospholipids, eventually making them permeable [146,147]. Change of the permeability for H^+ and K^+ cations affects cellular pH and damage of cellular organelles [148,149]. Additionally, essential oils inhibit the synthesis of fungal DNA, RNA, proteins, and polysaccharides [150]. Essential oils can also disintegrate mitochondrial membrane [151,152]. It has also been shown that essential oil from *Thymus vulgaris* inhibits the production of aflatoxins by *Aspergillus flavus* and leads to the reduction of ergosterol production [123].

Table 3. Minimal inhibitory concentrations (MICs) of essential oils against fungi.

Source of the Essential Oil	Targeted Fungus	MICs (µg/mL; µl/mL)	Reference(s)
Aeollanthus suaveolens Mart. ex Spreng. = *A. heliotropioides* Oliv.	*Candida albicans*	1200–5000	[34]
	Candida glabrata	5000	[34]
	Candida krusei	2500	[34]
	Candida parapsilosis	2500	[34]
	Candida tropicalis	1200	[34]
	Cryptococcus neoformans	600–5000	[34]
Agastache rugosa (Fisch. and C.A.Mey.) Kuntze	*Aspergillus flavus*	10,000	[153]
	Aspergillus niger	5000	[153]
	Blastoschizomyces capitatus	5000	[153]
	Candida albicans	28–5000	[153,154]
	Candida utilis	5000	[153]
	Candida tropicalis	5000	[153]
	Cryptococcus neoformans	10,000	[153]
	Trichoderma viride	5000	[153]
	Trichophyton erinacei	780	[153]
	Trichophyton mentagrophytes	3120	[153]
	Trichophyton rubrum	1560	[153]
	Trichophyton schoenleinii	1560	[153]
	Trichophyton soudanense	1560	[153]
	Trichophyton tonsurans	10,000	[153]
	Trichosporon mucoides	5000	[153]
Ballota nigra subsp. *foetida* (Vis.) Hayek	*Alternaria solani*	750	[37]
	Botrytis cinerea	600	[37]
	Fusarium coeruleum	350	[37]
	Fusarium culmorum	300	[37]
	Fusarium oxysporum	300	[37]
	Fusarium solani	350	[37]
	Fusarium sporotrichioides	350	[37]
	Fusarium tabacinum	350	[37]
	Fusarium verticillioides	300	[37]
Clinopodium dalmaticum (Benth.) Bräuchler and Heubl = *Micromeria dalmatica* Benth.	*Aspergillus niger*	0.4	[38]
	Aspergillus ochraceus	0.4	[38]
	Cladosporium cladosporioides	0.4	[38]
	Fusarium tricinctum	0.4	[38]
	Penicilium ochrochloron	0.4	[38]
	Phomopsis helianthi	0.2	[38]
	Trichoderma viride	0.4	[38]
Clinopodium nepeta subsp. *glandulosum* (Req.) Govaerts = *Calamintha glandulosa* (Req.) Bentham = *Calamintha officinalis* Moench	*Aspergillus niger*	1250	[39]
	Candida albicans	2500	[39]

Table 3. *Cont.*

Source of the Essential Oil	Targeted Fungus	MICs (µg/mL; µl/mL)	Reference(s)
Clinopodium nepeta (L.) Kuntze = *Calamintha nepeta* (L.) Savi	*Aspergillus flavus*	1.25–10	[41]
	Aspergillus fumigatus	0.64–5	[41]
	Aspergillus niger	0.32–10	[41]
	Candida albicans	1.25–12,480	[41,42]
	Candida guillermondii	1.25–2.5	[41]
	Candida krusei	1.25–2.5	[41]
	Candida parapsilosis	1.25–2.5	[41]
	Candida tropicalis	1.25–2.5	[41]
	Cryptococcus neoformans	0.32–1.25	[41]
	Epidermophyton floccosum	0.64–2.5	[41]
	Microsporum canis	0.64–2.5	[41]
	Microsporum gypseum	1.25–5	[41]
	Trichophyton mentagrophytes	0.64–5	[41]
	Trichophyton rubrum	0.64–5	[41]
Clinopodium thymifolium (Scop.) Kuntze = *Micromeria thymifolia* (Scop.) Fritsch	*Aspergillus niger*	2	[38]
	Aspergillus ochraceus	2	[38]
	Cladosporium cladosporioides	2	[38]
	Fusarium tricinctum	2	[38]
	Penicillium ochrochloron	2	[38]
	Phomopsis helianthi	0.4	[38]
	Trichoderma viride	2	[38]
Clinopodium umbrosum (M.Bieb.) Kuntze = *Calamintha umbrosa* Benth.	*Alternaria solani*	3000	[43]
	Fusarium oxysporum	2000	[43]
	Helminthosporium maydis	1500	[43]
Dracocephalum heterophyllum Benth.	*Alternaria solani*	625	[155]
	Candida albicans	625–1000	[44,155]
	Epidermophyton floccosum	2500	[155]
	Fusarium semitectum	313	[155]
Hymenocrater longiflorus Benth.	*Aspergillus niger*	480	[45]
	Candida albicans	240	[45]
Hyptis ovalifolia Benth.	*Microsporum canis*	15.6–1000	[46,156]
	Microsporum gypseum	7.8–1000	[46,156]
	Trichophyton mentagrophytes	15.6–1000	[46,156]
	Trichophyton rubrum	7.8–1000	[46,156]
Hyssopus officinalis L.	*Aspergillus niger*	52,200	[47]
	Aspergillus ochraceus	26,100	[47]
	Aspergillus versicolor	10,440	[47]
	Candida albicans	128–1000	[44,48]
	Candida glabrata	512–1024	[48]
	Candida krusei	128–256	[48]
	Candida parapsilosis	256–512	[48]
	Candida tropicalis	512–1024	[48]
	Cladosporium cladosporioides	10,440	[47]
	Cladosporium fulvum	26,100	[47]
	Penicillium funiculosum	52,200	[47]
	Penicillium ochrochloron	26,100	[47]
	Trichoderma viride	10,440	[47]
Lavandula angustifolia Mill.	*Candida albicans*	0.125–512	[50,51,157]
	Malassezia furfur	>4	[49]
	Trichophyton rubrum	1–512	[49,51]
	Trichosporon beigelii	2	[49]
Lavandula multifida L.	*Aspergillus flavus*	0.64	[52]
	Aspergillus fumigatus	0.32	[52]
	Aspergillus niger	0.32	[52]
	Candida albicans	0.32	[52]
	Candida guilliermondii	0.32	[52]
	Candida krusei	0.64	[52]
	Candida parapsilosis	0.32	[52]
	Candida tropicalis	0.32	[52]
	Cryptococcus neoformans	0.16	[52]
	Epidermophyton floccosum	0.16	[52]
	Microsporum canis	0.16	[52]
	Microsporum gypseum	0.16	[52]
	Trichophyton mentagrophytes	0.16	[52]
	Trichophyton mentagrophytes var. interdigitale	0.16	[52]
	Trichophyton rubrum	0.16	[52]
	Trichophyton verrucosum	0.16	[52]

Table 3. *Cont.*

Source of the Essential Oil	Targeted Fungus	MICs (µg/mL; µl/mL)	Reference(s)
Lavandula pedunculata (Miller) Cav.	*Aspergillus flavus*	5–10	[53]
	Aspergillus fumigatus	2.5–5	[53]
	Aspergillus niger	5	[53]
	Candida albicans	2.5	[53]
	Candida guillermondii	1.25	[53]
	Candida krusei	1.25–2.5	[53]
	Candida parapsilosis	2.5–5	[53]
	Candida tropicalis	1.25–2.5	[53]
	Cryptococcus neoformans	0.32–1.25	[53]
	Epidermophyton floccosum	0.32–0.64	[53]
	Microsporum canis	0.32–1.25	[53]
	Microsporum gypseum	0.64–2.5	[53]
	Trichophyton mentagrophytes	0.64–1.25	[53]
	Trichophyton rubrum	0.32–1.25	[53]
Lavandula stoechas L.	*Aspergillus flavus*	1.25–10	[54]
	Aspergillus fumigatus	0.64–1.25	[54]
	Aspergillus niger	0.32–1.25	[54]
	Candida albicans	0.64–512	[51,54]
	Candida guillermondii	1.25	[54]
	Candida krusei	2.5	[54]
	Candida parapsilosis	2.5	[54]
	Candida tropicalis	2.5	[54]
	Cryptococcus neoformans	0.64	[54]
	Epidermophyton floccosum	0.16–0.32	[54]
	Microsporum canis	0.16–0.64	[54]
	Microsporum gypseum	0.32–0.64	[54]
	Trichophyton mentagrophytes	0.32–0.64	[54]
	Trichophyton mentagrophytes var. interdigitale	0.16–0.64	[54]
	Trichophyton rubrum	0.16–256	[51,54]
	Trichophyton verrucosum	0.32	[54]
Lavandula viridis L'Her.	*Aspergillus flavus*	5	[55]
	Aspergillus fumigatus	2.5	[55]
	Aspergillus niger	2.5	[55]
	Candida albicans	1.25–2.5	[55]
	Candida guillermondii	0.64–1.25	[55]
	Candida krusei	1.25–2.5	[55]
	Candida parapsilosis	1.25	[55]
	Candida tropicalis	1.25–2.5	[55]
	Cryptococcus neoformans	0.64	[55]
	Epidermophyton floccosum	0.32	[55]
	Microsporum canis	0.32	[55]
	Microsporum gypseum	0.64	[55]
	Trichophyton mentagrophytes	0.32–0.64	[55]
	Trichophyton mentagrophytes var. interdigitale	0.32–0.64	[55]
	Trichophyton rubrum	0.32	[55]
	Trichophyton verrucosum	0.32	[55]
Lepechinia mutica (Benth.) Epling	*Candida albicans*	>9000	[56]
	Fusarium graminearum	>9000	[56]
	Microsporum canis	2200–4500	[56]
	Pyricularia oryzae	>9000	[56]
	Trichophyton rubrum	2200–4500	[56]
Marrubium vulgare L.	*Aspergillus niger*	>1180	[58]
	Botrytis cinerea	>1100	[58]
	Fusarium solani	>1190	[58]
	Penicillium digitatum	>1120	[58]
Melissa officinalis L.	*Aspergillus niger*	313	[158]
	Candida albicans	30–313	[59,158]
	Cryptococcus neoformans	78	[158]
	Epidermophyton floccosum	30	[59]
	Microsporum canis	30	[59]
	Penicillium verrucosum	125	[159]
	Trichophyton mentagrophytes var. mentagrophytes	15	[59]
	Trichophyton rubrum	15	[59]
	Trichophyton tonsurans	15	[59]

Table 3. *Cont.*

Source of the Essential Oil	Targeted Fungus	MICs (µg/mL; µl/mL)	Reference(s)
Mentha cervina L.	*Aspergillus flavus*	2.5–5	[60]
	Aspergillus fumigatus	1.25–2.5	[60]
	Aspergillus niger	1.25–2.5	[60]
	Candida albicans	1.25–2.5	[60]
	Candida guillermondii	1.25–2.5	[60]
	Candida krusei	1.25–2.5	[60]
	Candida parapsilosis	1.25–2.5	[60]
	Candida tropicalis	1.25–2.5	[60]
	Cryptococcus neoformans	1.25	[60]
	Epidermophyton floccosum	0.64–1.25	[60]
	Microsporum canis	1.25	[60]
	Microsporum gypseum	1.25–2.5	[60]
	Trichophyton mentagrophytes	1.25–2.5	[60]
	Trichophyton rubrum	1.25	[60]
Mentha × piperita L.	*Aspergillus flavus*	1450–5000	[62,64]
	Aspergillus niger	625–10,000	[64,158]
	Aspergillus parasiticus	2500	[64]
	Candida albicans	225–1125	[63,158,160]
	Candida glabrata	225	[62]
	Candida tropicalis	225–230	[62]
	Cryptococcus neoformans	313	[158]
	Fusarium oxysporum	125	[161]
	Penicillium chrysogenum	1250	[64]
	Penicillium minioluteum	2050–2200	[62]
	Penicillium oxalicum	1300–2050	[62]
	Penicillium verrucosum	2500	[90]
Mentha pulegium L.	*Aspergillus niger*	0.25–1.25	[65,162]
	Aspergillus flavus	1.25	[162]
	Aspergillus fumigatus	1.25	[162]
	Candida albicans	0.94–3.75	[65,66,162, 163]
	Candida bracarensis	3.75	[163]
	Candida guillermondii	1.25	[162]
	Candida krusei	0.94–1.25	[162,163]
	Candida parapsilosis	1.25	[162]
	Candida tropicalis	1.25	[162]
	Cryptococcus neoformans	0.64	[162]
	Epidermophyton floccosum	1.25	[162]
	Microsporum canis	1.25	[162]
	Microsporum gypseum	1.25–2.5	[162]
	Saccharomyces cervisiae	<0.3–0.94	[66,163]
	Trichophyton mentagrophytes	1.25–2.5	[162]
	Trichophyton mentagrophytes var. interdigitale	2.5	[162]
	Trichophyton rubrum	1.25	[162]
	Trichophyton verrucosum	1.25	[162]
Mentha requienii Bentham	*Alternaria* spp.	>40	[67]
	Aspergillus fumigatus	>60	[67]
	Candida albicans	0.94–40	[67,163]
	Candida bracarensis	3.75	[163]
	Candida krusei	0.94	[163]
	Fusarium spp.	>40	[67]
	Penicillum spp.	>60	[67]
	Rhodotorula spp.	45	[67]
	Saccharomyces cerevisiae	0.94	[163]
Mentha spicata L.	*Aspergillus flavus*	1.25	[162]
	Aspergillus fumigatus	0.64	[162]
	Aspergillus niger	0.64–313	[158,162]
	Candida albicans	1.25–625	[51,158,162]
	Candida guillermondii	1.25	[162]
	Candida krusei	1.25	[162]
	Candida parapsilosis	1.25	[162]
	Candida tropicalis	1.25	[162]
	Cryptococcus neoformans	0.32–313	[158,162]
	Epidermophyton floccosum	0.64	[162]
	Fusarium graminearum	2.5	[164]
	Fusarium moniliforme	2.5	[164]
	Malassezia furfur	>4	[49]
	Microsporum canis	0.64–2	[68,162]

Table 3. *Cont.*

Source of the Essential Oil	Targeted Fungus	MICs (µg/mL; µl/mL)	Reference(s)
	Microsporum gypseum	0.64–3	[162]
	Penicillium corylophilum	0.625	[165]
	Penicillium expansum	2.5	[164]
	Trichophyton erinacei	3	[68]
	Trichophyton mentagrophytes	0.64–3	[68,162]
	Trichophyton mentagrophytes var. interdigitale	0.64	[162]
	Trichophyton rubrum	0.25–512	[49,51,162]
	Trichophyton terrestre	3	[68]
	Trichophyton verrucosum	0.32	[162]
	Trichosporon beigelii	0.25	[49]
Mentha suaveolens Ehrh.	*Candida albicans*	0.34–1250	[69,71,166]
	Candida glabrata	0.69–2.77	[69]
	Cryptococcus neoformans	300	[167]
	Microsporum canis	1250	[167]
	Microsporum gypseum	1250	[167]
	Trichophyton mentagrophytes	600–1250	[167]
	Trichophyton rubrum	5000	[167]
	Trichophyton violaceum	600	[167]
Micromeria albanica (Griseb. ex K. Maly) Silic	*Aspergillus niger*	0.2	[38]
	Aspergillus ochraceus	0.2	[38]
	Cladosporium cladosporioides	0.2	[38]
	Fusarium tricinctum	0.4	[38]
	Penicilium ochrochloron	0.2	[38]
	Phomopsis helianthi	0.2	[38]
	Trichoderma viride	0.4	[38]
Moluccella spinosa L.	*Aspergillus niger*	50	[72]
	Candida albicans	100	[72]
	Fusarium oxysporum	100	[72]
Nepeta ciliaris Benth. = *Nepeta leucophylla* Benth.	*Alternaria solani*	3000	[43]
	Candida albicans	0.78	[168]
	Fusarium oxysporum	1000	[43]
	Trichophyton rubrum	0.19	[168]
	Helminthosporium maydis	1500	[43]
Nepeta clarkei Hook. f.	*Alternaria solani*	3000	[43]
	Fusarium oxysporum	2000	[43]
	Helminthosporium maydis	2000	[43]
Ocimum basilicum L.	*Aspergillus flavus*	10,000	[64]
	Aspergillus fumigatus	>50	[75]
	Aspergillus niger	>50–10,000	[64,75,158]
	Aspergillus parasiticus	5000	[64]
	Candida albicans	30–625	[73,74,158]
	Candida guilliermondii	3.125–6.25	[76]
	Cryptococcus neoformans	313–1250	[158,169]
	Debaryomyces hansenii	6.25	[76]
	Epidermophyton floccosum	15	[74]
	Microsporum canis	1–15.2	[68,74]
	Microsporum gypseum	3	[68]
	Penicillium chrysogenum	10,000	[64]
	Penicillium italicum	>50	[75]
	Rhizopus stolonifer	>50	[75]
	Rhodotorula glutinis	86	[73]
	Trichophyton erinacei	2.5	[68]
	Trichophyton mentagrophytes	2.5–8.3	[68,74]
	Trichophyton terrestre	3	[68]
	Saccharomyces cerevisiae	28	[73]
	Schizosaccharomyces pombe	86	[73]
	Trichophyton rubrum	8.3	[74]
	Trichophyton tonsurans	8	[74]
	Yarrowia lypolytica	57	[73]
Ocimum × *africanum* Lour. = *Ocimum* × *citriodorum*	*Candida guilliermondii*	3.125	[76]
	Debaryomyces hansenii	1.56	[76]

Table 3. *Cont.*

Source of the Essential Oil	Targeted Fungus	MICs (µg/mL; µl/mL)	Reference(s)
Ocimum campechianum Mill. = *Ocimum micranthum* Willd.	*Candida albicans*	69	[73]
	Rhodotorula glutinis	139	[73]
	Saccharomyces cerevisiae	69	[73]
	Schizosaccharomyces pombe	104	[73]
	Yarrowia lypolytica	69	[73]
Ocimum forskolei Benth.	*Candida albicans*	35.3–8600	[77,170]
Ocimum gratissimum L.	*Aspergillus fumigatus*	>1000	[78]
	Candida albicans	350–1500	[78,171]
	Candida krusei	750	[171]
	Candida parapsilosis	380	[171]
	Candida tropicalis	1500	[171]
	Cryptococcus neoformans	250–300	[78,79]
	Fusarium oxysporum f. sp. *cubense*	62.5	[80]
	Fusarium oxysporum f. sp. *lycopersici*	31.25	[80]
	Fusarium oxysporum f. sp. *tracheiphilum*	62.5	[80]
	Fusarium solani	62.5	[80]
	Macrophomina phaseolina	62.5–125	[80]
	Malassezia pachydermatis	300	[78]
	Microsporum canis	200–500	[78,172]
	Microsporum gypseum	150–250	[78,172]
	Rhizoctonia solani	31.25	[80]
	Scopulariopsis brevicaulis	400	[78]
	Trichophyton interdigitale	250	[78]
	Trichophyton mentagrophytes	200–250	[78,172]
	Trichophyton rubrum	150–250	[78,172]
Ocimum tenuiflorum L. = *Ocimum sanctum* L.	*Aspergillus flavus*	300	[83]
	Candida albicans	0.1–300	[81,82]
	Candida glabrata	0.15–300	[81,82]
	Candida krusei	0.35–450	[81,82]
	Candida parapsilosis	0.25–500	[81,82]
	Candida tropicalis	0.1–300	[81,82]
Origanum compactum Benth.	*Alternaria alternata*	300	[84]
	Bipolaris oryzae	300	[84]
	Fusarium equiseti	300	[84]
	Fusarium graminearum	300	[84]
	Fusarium verticillioides	300	[84]
Origanum majorana L.	*Aspergillus flavus*	450–650	[62]
	Aspergillus niger	625	[158]
	Botrytis cinerea	5000	[87]
	Candida albicans	625	[158]
	Cryptococcus neoformans	313	[158]
	Fusarium delphinoides	1800–14,400	[85]
	Fusarium incarnatum-equiseti	450–3600	[85]
	Fusarium napiforme	3600–14,400	[85]
	Fusarium oxysporum	900–3600	[85]
	Fusarium solani	900–3600	[85]
	Fusarium verticillioides	14,400	[85]
	Microsporum canis	0.5	[68]
	Microsporum gypseum	2	[68]
	Penicillium expansum	10,000	[87]
	Penicillium minioluteum	400–500	[62]
	Penicillium oxalicum	350–400	[62]
	Sporothrix brasiliensis	≤2250–9000	[86]
	Sporothrix schenckii	≤2250–9000	[86]
	Trichophyton erinacei	1	[68]
	Trichophyton mentagrophytes	1.5	[68]
	Trichophyton terrestre	2	[68]

Table 3. *Cont.*

Source of the Essential Oil	Targeted Fungus	MICs (µg/mL; µl/mL)	Reference(s)
Origanum vulgare L.	*Aspergillus flavus*	0.64–2500	[64,89,91]
	Aspergillus fumigatus	0.32–0.64	[89]
	Aspergillus niger	0.32–623	[62,89,91,158]
	Aspergillus ochraceus	470	[91]
	Aspergillus parasiticus	2500	[64]
	Candida albicans	0.32–700	[74,88,89,91,158]
	Candida glabrata	350	[88]
	Candida guillermondii	0.64–1.25	[89]
	Candida krusei	0.64–700	[88,89]
	Candida parapsilosis	0.64–170	[88,89]
	Candida tropicalis	0.32–700	[88,89]
	Cladosporium sp.	0.05–0.3	[173]
	Cryptococcus neoformans	0.16–78	[89,158]
	Epidermophyton floccosum	0.32–2	[74,89]
	Fusarium sp.	0.1–0.5	[173]
	Malassezia furfur	1–780	[49,174]
	Microsporum canis	0.025–2	[68,74,89]
	Microsporum gypseum	0.025–1.25	[68,89]
	Penicillium sp.	0.1–0.5	[173]
	Penicillium chrysogenum	625	[64]
	Penicillium corylophilum	0.625	[165]
	Penicillium funiculosum	610	[91]
	Penicillium ochrochloron	710	[91]
	Penicillium verrucosum	1.1719	[90,91]
	Trichophyton mentagrophytes	0.32–1.25	[74,89]
	Trichophyton rubrum	0.16–1.25	[49,74,89]
	Trichophyton tonsurans	1	[74]
	Trichosporon beigelii	0.25	[49]
	Trichophyton erinacei	0.5	[68]
	Trichophyton mentagrophytes	0.5	[68]
	Trichophyton terrestre	0.25	[68]
Pogostemon cablin (Blanco) Benth.	*Aspergillus flavus*	>1500	[92]
	Aspergillus niger	156	[158]
	Aspergillus oryzae	>1500	[92]
	Candida albicans	32–625	[158,175]
	Candida krusei	64–257	[175]
	Candida tropicalis	32–257	[175]
	Cryptococcus neoformans	20	[158]
Pogostemon heyneanus Benth.	*Candida albicans*	6000	[176]
	Candida glabrata	6000	[176]
	Candida tropicalis	10,000	[176]
Premna microphylla Turcz.	*Aspergillus niger*	>500	[94]
	Candida albicans	>500	[94]
	Fusarium oxysporum	>500	[94]
Rosmarinus officinalis L.	*Aspergillus flavus*	330	[91]
	Aspergillus ochraceus	590	[91]
	Aspergillus niger	380–10,000	[91,98,158]
	Botrytis cinerea	2500	[87]
	Candida albicans	30.2–1000	[51,91,96,98,158]
	Cryptococcus neoformans	313	[158]
	Epidermophyton floccosum	30	[96]
	Microsporum canis	2.5–30.2	[68,96]
	Microsporum gypseum	2.5	[68]
	Penicillium expansum	5000	[87]
	Penicillium ochrochloron	470	[91]
	Penicillium funiculosum	570	[91]
	Trichophyton erinacei	1.5	[68]
	Trichophyton mentagrophytes	5–15.3	[68,96]
	Trichophyton rubrum	15–256	[51,96]
	Trichophyton terrestre	5	[68]
	Trichophyton tonsurans	15.2	[96]

Table 3. *Cont.*

Source of the Essential Oil	Targeted Fungus	MICs (µg/mL; µl/mL)	Reference(s)
Salvia fruticosa Miller	*Candida albicans*	512	[51]
	Fusarium oxysporum f. sp. *dianthi*	>2000	[99]
	Fusarium proliferatum	>2000	[99]
	Fusarium solani f. sp. *cucurbitae*	>2000	[99]
	Malassezia furfur	>4	[99]
	Rhizoctonia solani	>2000	[99]
	Sclerotinia sclerotiorum	>2000	[99]
	Trichophyton rubrum	2–256	[49,99]
	Trichosporon beigelii	4	[49]
Salvia mirzayanii Rech. f. and Esfand	*Candida albicans*	0.5–2	[100]
	Candida krusei	1	[100]
	Candida dubliniensis	0.06–0.5	[100]
	Candida glabrata	0.06–1	[100]
	Candida parapsilosis	0.25–1	[100]
	Candida tropicalis	0.25–2	[100]
	Trichosporon sp.	1	[100]
Salvia officinalis L.	*Aspergillus flavus*	5–10	[101]
	Aspergillus fumigatus	2.5–5	[101]
	Aspergillus niger	5–1250	[101,158]
	Candida albicans	2.5–2780	[96,101,158,177]
	Candida guillermondii	1.25–2.5	[101]
	Candida krusei	2.5–5	[101]
	Candida parapsilosis	5	[101]
	Candida tropicalis	5	[101]
	Cryptococcus neoformans	0.64–625	[101,158]
	Epidermophyton floccosum	0.64–100	[96,101]
	Microsporum canis	1.25–100.2	[96,101]
	Microsporum gypseum	1.25–2.5	[101]
	Trichophyton mentagrophytes	1.25–60	[96,101]
	Trichophyton mentagrophytes var. interdigitale	1.25	[101]
	Trichophyton rubrum	0.64–60	[96,101]
	Trichophyton tonsurans	60	[96]
	Trichophyton verrucosum	1.25–2.5	[101]
Salvia sclarea L.	*Aspergillus niger*	1250	[158]
	Candida albicans	1250	[158]
	Cryptococcus neoformans	313	[158]
	Fusarium delphinoides	1800–3600	[85]
	Fusarium incarnatum-equiseti	1800–3600	[85]
	Fusarium napiforme	1800–3600	[85]
	Fusarium oxysporum	1800–3600	[85]
	Fusarium solani	3600–7200	[85]
	Fusarium verticillioides	1800	[85]
Satureja hortensis L.	*Alternaria alternata*	62.5	[103]
	Aspergillus flavus	31.25–500	[103,104,117]
	Aspergillus niger	471	[117]
	Aspergillus ochraceus	423	[117]
	Aspergillus parasiticus	373	[117]
	Aspergillus terreus	389	[117]
	Aspergillus variecolor	125	[103]
	Candida albicans	200–400	[103,178]
	Fusarium culmorum	125	[103]
	Fusarium oxysporum	250	[103]
	Microsporum canis	62.5	[103]
	Moniliania fructicola	31.25	[103]
	Penicillium spp.	125	[103]
	Rhizoctonia solani	125	[103]
	Rhizopus spp.	250	[103]
	Sclerotinia minor	250	[103]
	Sclerotinia sclerotiorum	125	[103]
	Trichophyton mentagrophytes	62.5	[103]
	Trichophyton rubrum	31.25	[103]
Satureja montana L.	*Microsporum canis*	0.5	[68]
	Microsporum gypseum	2	[68]
	Trichophyton erinacei	2	[68]
	Trichophyton mentagrophytes	2	[68]
	Trichophyton terrestre	3	[68]

Table 3. *Cont.*

Source of the Essential Oil	Targeted Fungus	MICs (µg/mL; µl/mL)	Reference(s)
Satureja thymbra L.	*Aspergillus flavus*	25	[105]
	Aspergillus fumigatus	1.25–25	[105,179]
	Aspergillus niger	2.5–25	[105,179]
	Aspergillus ochraceus	2.5–25	[105,179]
	Aspergillus versicolor	1.25	[179]
	Candida albicans	25–128	[51,105]
	Penicillium funiculosum	2.5–25	[105,179]
	Penicillium ochrochloron	1–1.25	[105,179]
	Trichoderma viride	1.25–25	[105,179]
	Trichophyton rubrum	128	[51]
Stachys cretica L.	*Candida albicans*	625	[106]
Stachys officinalis (L.) Trevis	*Aspergillus niger*	2500	[107]
	Candida albicans	5000	[107]
Stachys pubescens Ten.	*Alternaria alternata*	1	[108]
	Aspergillus flavus	0–5	[108]
	Fusarium oxysporum	1	[108]
Teucrium sauvagei Le Houerou	*Aspergillus fumigatus*	>1000	[109]
	Candida albicans	>1000	[109]
	Cryptococcus neoformans	>1000	[109]
	Epidermophyton floccosum	850	[109]
	Microsporum canis	800	[109]
	Microsporum gypseum	900	[109]
	Scopulariopsis brevicaulis	>1000	[109]
	Scytalidium dimidiatum	>1000	[109]
	Trichophyton mentagrophytes var. *interdigitale*	950	[109]
	Trichophyton mentagrophytes var. *mentagrophytes*	900	[109]
	Trichophyton rubrum	800	[109]
	Trichophyton soudanense	800	[109]
Teucrium yemense Deflers.	*Aspergillus niger*	313	[77]
	Botrytis cinerea	313	[77]
	Candida albicans	1250	[77]
Thymbra capitata (L.) Cav. = *Thymus capitatus* (L.) Hoffmanns. and Link = *Coridothymus capitatus* (L.) Rchb.f. Solms	*Aspergillus flavus*	0.32	[111]
	Aspergillus fumigatus	0.16–0.32	[111]
	Aspergillus niger	0.1–0.16	[111,180]
	Aspergillus oryzae	0.2	[180]
	Candida albicans	0.16–128	[51,110–112]
	Candida glabrata	0.32	[111,112]
	Candida guilliermondii	0.16–0.32	[111,112]
	Candida krusei	0.32	[111]
	Candida parapsilosis	0.32	[111,112]
	Candida tropicalis	0.32	[111,112]
	Epidermophyton floccosum	0.08	[111]
	Fusarium solani	0.2	[180]
	Microsporum canis	0.08	[111]
	Microsporum gypseum	0.08	[111]
	Penicillium digitatum	0.5	[180]
	Trichophyton mentagrophytes	0.08	[111]
	Trichophyton rubrum	0.16–64	[51,111]
Thymbra spicata L.	*Aspergillus fumigatus*	0.3	[179]
	Aspergillus niger	0.6	[179]
	Aspergillus versicolor	0.3	[179]
	Aspergillus ochraceus	0.6	[179]
	Candida albicans	1.12–3750	[51,113,114]
	Candida krusei	1.12	[114]
	Candida parapsilosis	0.6–1.12	[114]
	Penicillium funiculosum	0.3	[179]
	Penicillium ochrochloron	0.3	[179]
	Trichoderma viride	0.3	[179]
	Trichophyton rubrum	64	[51]
Thymus bovei Benth.	*Candida albicans*	250	[115]
Thymus daenensis Celak.	*Alternaria alternata*	>8	[108]
	Aspergillus flavus	1	[108]
	Fusarium oxysporum	4	[108]

Table 3. *Cont.*

Source of the Essential Oil	Targeted Fungus	MICs (µg/mL; µl/mL)	Reference(s)
Thymus kotschyanus Boiss. and Hohen.	*Alternaria alternata*	1	[108]
	Aspergillus flavus	0.5	[108]
	Fusarium oxysporum	0–5	[108]
Thymus mastichina (L.) L.	*Candida albicans*	1.25–2.5	[116]
	Candida glabrata	1.25–1.5	[116]
	Candida guilliermondii	1.25	[116]
	Candida krusei	1.25–2.5	[116]
	Candida parapsilosis	2.5–5	[116]
	Candida tropicalis	2.5–10	[116]
Thymus migricus Klokov et Des.-Shost.	*Aspergillus flavus*	452	[117]
	Aspergillus niger	460	[117]
	Aspergillus ochraceus	430	[117]
	Aspergillus parasiticus	581	[117]
	Aspergillus terreus	447	[117]
Thymus pulegioides L.	*Aspergillus flavus*	0.32	[119]
	Aspergillus fumigatus	0.16	[119]
	Aspergillus niger	0.32	[119]
	Candida albicans	0.32–0.64	[119]
	Candida glabrata	0.32–0.64	[119]
	Candida guilliermondii	0.32	[119]
	Candida krusei	0.32–0.64	[119]
	Candida parapsilosis	0.64	[119]
	Candida tropicalis	0.32–0.64	[119]
	Epidermophyton floccosum	0.16	[119]
	Microsporum canis	0.16	[119]
	Microsporum gypseum	0.16	[119]
	Trichophyton mentagrophytes	0.16	[119]
	Trichophyton rubrum	0.32	[119]
Thymus schimperi Ronninger	*Aspergillus minutus*	0.512–2	[120]
	Aspergillus niger	0.16	[181]
	Aspergillus tubingensis	1–4	[120]
	Beauveria bassiana	0.128–1	[120]
	Candida albicans	0.16	[181]
	Microsporum spp.	0.08	[181]
	Microsporum gypseum	0.128–1	[120]
	Penicillium chrysogenum	0.512–2	[120]
	Rhodotorula spp.	0.08	[181]
	Tricophyton spp.	0.08–0.31	[181]
	Verticillium sp.	0.512–2	[120]
Thymus serpyllum L.	*Aspergillus carbonarius*	1.25	[182]
	Aspergillus ochraceus	0.625	[182]
	Aspergillus niger	2.5	[182]
	Microsporum canis	0.025	[68]
	Microsporum gypseum	0.25	[68]
	Trichophyton erinacei	0.1	[68]
	Trichophyton mentagrophytes	0.2	[68]
	Trichophyton terrestre	0.1	[68]
Thymus striatus Vahl.	*Alternaria alternata*	1	[121]
	Aspergillus flavus	1.5	[121]
	Aspergillus niger	1	[121]
	Aspergillus ochraceus	1	[121]
	Aspergillus terreus	1	[121]
	Aspergillus versicolor	1	[121]
	Cladosporium cladosporioides	0.5	[121]
	Epidermophyton floccosum	1	[121]
	Microsporum canis	1.5	[121]
	Penicillium funiculosum	2	[121]
	Penicillium ochrochloron	2	[121]
	Phomopsis helianthi	0.5	[121]
	Trichoderma viride	2	[121]
	Trichophyton mentagrophytes	1	[121]

Table 3. *Cont.*

Source of the Essential Oil	Targeted Fungus	MICs (µg/mL; µl/mL)	Reference(s)
Thymus vulgaris L.	*Absidia* spp.	7 ± 4	[122]
	Alternaria spp.	9.4 ± 4.5	[122]
	Alternaria alternata	4.7–500	[122,183]
	Aspergillus spp.	3.2	[122]
	Aspergillus flavus	9.35–1500	[64,104,122,125,184]
	Aspergillus fumigatus	144–1000	[124,184]
	Aspergillus niger	9.35–1250	[64,122,158,184]
	Aspergillus ochraceus	2.5–750	[164,184]
	Aspergillus parasiticus	1250	[64]
	Aspergillus sulphureus	10.88 ± 3.1	[122]
	Aspergillus versicolor	9.6 ± 9.25	[122]
	Botrytis cinerea	312	[87]
	Candida albicans	0.16–313	[73,74,116,158]
	Candida glabrata	0.16–0.32	[116]
	Candida krusei	0.08–0.16	[116]
	Candida guillermondii	0.16	[116]
	Candida parapsilosis	0.16–0.32	[116]
	Candida tropicalis	0.16–0.32	[116]
	Chaetomium globosum	1.6	[122]
	Cladosporium spp.	12.8	[122]
	Cladosporium sphaerospermum	19.6	[122]
	Cryptococcus neoformans	78	[158]
	Epidermophyton floccosum	4	[74]
	Fusarium spp.	62.5	[185]
	Fusarium delphinoides	900–1800	[85]
	Fusarium incarnatum-equiseti	450–3600	[85]
	Fusarium napiforme	900	[85]
	Fusarium oxysporum	5–900	[85,126]
	Fusarium solani	1800–3600	[85]
	Fusarium verticillioides	900	[85]
	Malassezia furfur	920	[174]
	Microsporum canis	2.2	[74]
	Mortierella spp.	250	[185]
	Mucor spp.	50.2 ± 8.4	[122]
	Penicilium spp.	18.95–500	[122,185]
	Penicilium brevicompactum	19.6	[122]
	Penicillium chrysogenum	312.5–1750	[64,184]
	Penicilium chrysogenum	19.6	[122]
	Penicillium citrinum	1250	[184]
	Penicillium expansum	625	[87]
	Penicillium griseofulvum	19.6	[122]
	Rhizopus spp.	12.6	[122]
	Rhodotorula glutinis	72	[73]
	Rhizopus oryzae	256–512	[123]
	Saccharomyces cerevisiae	72	[73]
	Schizosaccharomyces pombe	36	[73]
	Stachybotrys chartarum	6.2	[122]
	Trichoderma spp.	16.8	[122]
	Trichophyton mentagrophytes	2.2	[74]
	Trichophyton rubrum	2–72	[74,124]
	Trichophyton tonsurans	2.2	[74]
	Ulocladium spp.	5.45 ± 1.5	[122]
	Yarrowia lypolytica	36	[73]
Thymus zygis L.	*Candida albicans*	0.16–0.32	[116]
	Candida glabrata	0.32	[116]
	Candida krusei	0.16–0.32	[116]
	Candida guillermondii	0.16	[116]
	Candida parapsilosis	0.32	[116]
	Candida tropicalis	0.16–0.32	[116]
	Penicillium corylophilum	0.3125–0.625	[165]

Table 3. *Cont.*

Source of the Essential Oil	Targeted Fungus	MICs (µg/mL; µl/mL)	Reference(s)
Vitex agnus-castus L.	*Candida albicans*	0.53–512	[51,129]
	Candida dubliniensis	0.27	[129]
	Candida famata	2.13	[129]
	Candida glabrata	0.27	[129]
	Candida krusei	0.27	[129]
	Candida lusitaniae	2.13	[129]
	Candida parapsilosis	1.06	[129]
	Candida tropicalis	0.13	[129]
	Epidermophyton floccosum	0.64–2.5	[128]
	Microsporum canis	0.64–5	[128]
	Microsporum gypseum	1.25–10	[128]
	Trichophyton mentagrophytes	1.25–10	[128]
	Trichophyton rubrum	0.64–512	[51,128]
Zataria multiflora Boiss.	*Aspergillus flavus*	358	[117]
	Aspergillus niger	358	[117]
	Aspergillus ochraceus	341	[117]
	Aspergillus parasiticus	367	[117]
	Aspergillus terreus	447	[117]
	Microsporum canis	0.125–0.25	[130]
	Microsporum gypseum	0.03–0.06	[130]
	Trichophyton mentagrophytes	0.03	[130]
	Trichophyton rubrum	0.03–0.06	[130]
	Trichophyton schoenleinii	0.125–0.6	[130]
Ziziphora clinopodioides Lam.	*Aspergillus flavus*	48.82	[184,186]
	Aspergillus fumigatus	1750	[184]
	Aspergillus niger	3000	[184]
	Aspergillus ochraceus	1500	[184]
	Aspergillus parasiticus	48.82	[186]
	Penicillium chrysogenum	3000	[184]
	Penicillium citrinum	1750	[184]
Ziziphora tenuior L.	*Aspergillus flavus*	1.25	[133]
	Aspergillus fumigatus	0.64	[133]
	Aspergillus niger	0.64	[133]
	Candida albicans	1.25	[133]
	Candida guillermondii	1.25	[133]
	Candida krusei	1.25	[133]
	Candida parapsilosis	1.25	[133]
	Candida tropicalis	1.25	[133]
	Cryptococcus neoformans	0.16	[133]
	Epidermophyton floccosum	0.64	[133]
	Microsporum canis	0.64–1.25	[133]
	Microsporum gypseum	1.25	[133]
	Trichophyton mentagrophytes	1.25	[133]
	Trichophyton mentagrophytes var. *interdigitale*	1.254	[133]
	Trichophyton rubrum	0.64	[133]
	Trichophyton verrucosum	0.64	[133]

4. Essential Oils of Lamiaceae Plants in Cosmetics and Medicines

Some essential oils of Lamiaceae family plants and/or their components are commonly used in cosmetics and less often in medicine. Essential oils from *Thymus vulgaris*, *Origanum vulgare*, *Rosmarinus officinalis*, *Calamintha officinalis*, *Salvia officinalis*, or *Lavandula officinalis* are in cosmetic formulations as natural preservatives [187]. *Lavandula angustifolia* oil is commonly used as a fragrance in cosmetics, soaps, perfumes and pharmaceutical products. It also acts as an anti-inflammatory, and is calming, headache relieving, is a sedative and is skin healing. Essential oils from *Lavandula hybrida* and *L. angustifolia* also have anti-louse activity. Compounds (essential oils and mainly menthol) extracted from *Mentha piperita* are commonly used as a fragrance in soaps, cosmetics and as well as in the kitchen as a spice and refreshing products. Moreover, they are often found in chewing gums, toothpastes, and mouthwashes. For medical use, it can be taken orally in gastrointestinal complications. *Rosmarinus officinalis* essential oil is often an ingredient as a fragrance in cosmetics, soaps, bath salts and oils, gels and ointments. It is widely used for hair care and hair-loss treatment because it promotes hair growth and helps against dandruff [188]. In medicine, essential oils from Lamiaceae family are used in aromatherapy (*Salvia sclarea*, *Lavandula officinalis*, *Mentha piperita*, *Rosmarinus officinalis*) [189], sinusitis (*Lavandula officinalis*, *Thymus vulgaris*) [190], and in upper respiratory tract for treatment of catarrh (*Mentha piperita*, *Mentha arvensis*, *Thymus* spp.) [191]. Both essential oils from Lamiaceae plants and mono-substances are used in toothpastes and mouthwashes. In many of these the following chemicals, like limonene, linalool, menthol, and thymol, are presented as flavorings and fragrances [192,193]. Additionally, in some toothpastes are essential oils, e.g., in "Parodontax®" occurs *Salvia officinalis* oil, *Mentha piperita* oil, and *Mentha arvensis* oil; in "Lacalut Active Herbal" is *Mentha arvensis* oil, *Thymus vulgaris* oil, and *Salvia officinalis* oil, while in "Signal Family Herbal Fresh" are oils from *Mentha piperita* and *Salvia officinalis* [194]. Literature data confirm a strong antifungal effect against *C. albicans* and anti-inflammatory activity of "Parodontax" toothpaste [195,196]. Besides toothpastes, also some medicines used to rinse the oral cavity or throat contain a large number of essential oils. Mention may be made of "Salviasept" having in its composition the oils from *Mentha* × *piperita*, *Thymus vulgaris*, *Thymus zygis*, *Origanum majorana,* and *Salvia officinalis* or "Dentosept Complex" containing oils from *Mentha piperita*, *Thymus vulgaris*, *Salvia* sp., *Lavandula* sp., and *Eucalyptus globulus*. Among the antifungal medicines in "Acerin Talk" antifungal foot deodorant are present *Lavandula* sp. oil, menthol, linalool, limonene, and geraniol, while in "Podoflex Tincture" for nails mucosis occur among others oils from *Salvia sclarea* and *Lavandula angustifolia* and mono-substances current in Lamiaceae plants: geraniol, limonene, linalool, citral, and eugenol [194].

5. Conclusions

More than half of the essential oils from Lamiaceae family plants have good antifungal activity (MICs < 1000 μg/mL). The microbiological data indicate that they could be used alone or in combination with antifungal drugs in the treatment of fungal infections, especially of the skin and mucous membranes. Some essential oils and their components extracted from Lamiaceae plants are used in cosmetics and medicines. Essential oils may be of future relevance in the treatment of multi-drug resistant fungi.

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