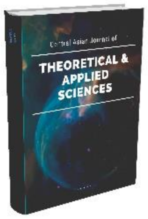

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Antifungal Activity of Different Eseential Oils

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Abstract: *Since ancient times, folk medicine and agro-food science have benefitted from the use of plant derivatives, such as essential oils, to combat different diseases, as well as to preserve food. In Nature, essential oils play a fundamental role in protecting the plant from biotic and abiotic attacks to which it may be subjected. Many researchers have analyzed in detail the modes of action of essential oils and most of their components. Citrus essential oils (CEOs) are a mixture of volatile compounds consisting mainly of monoterpene hydrocarbons and are widely used in the food and pharmaceutical industries because of their antifungal activities. To face the challenge of growing public awareness and concern about food and health safety, studies concerning natural biopreservatives have become the focus of multidisciplinary research efforts.*

Keywords: *antifungal, essential, oils, preserve, hydrocarbons, medicine, derivatives, monoterpene, health safety.*

Introduction

In a review article it was found that Safe and environmentally friendly plant-derived essential oils (EOs) have been reported effective against some pathogenic fungi. Growth on EO-amended growth medium and an inverted Petri plate assay were used to determine the effects of 38 oils and their volatiles on mycelial growth and spore germination of important pathogenic fungi and oomycetes: *Aphanomyces euteiches*, *Botrytis cinerea, Colletotrichum lentis, Didymella pisi, D. rabiei, D. lentis*, *Fusarium avenaceum, Stemphylium beticola, Sclerotinia sclerotiorum*, and *Pythium sylvaticum*. Palmarosa, oregano, clove, cinnamon, lemongrass, citronella, and thyme oils incorporated in media inhibited mycelial growth of all the pathogens by 100% at 1:1,000 to 1:4,000 dilution. In addition, thyme oil (1:500 dilution) showed complete inhibition of conidial germination (0% germination) of *F. avenaceum* and *D. pisi*. All seven EO volatiles inhibited mycelial growth of all pathogens by 50 to 100% except for *B. cinerea* and *S.*

sclerotiorum. EO effects on mycelial growth were fungistatic, fungicidal, or both and varied by EO. EOs show potential for management of major crop diseases in organic and conventional production systems.[1][2]

In another study, A total of 39 essential oils were tested for antifungal activities as volatile compounds against five phytopathogenic fungi at a dose of 1 μ l per plate. Five essential oils showed inhibitory activities against mycelial growth of at least one phytopathogenic fungus. *Origanum vulgare* essential oil inhibited mycelial growth of all of the five fungi tested. Both *Cuminum cyminum* and *Eucalyptus citriodora* oils displayed in vitro antifungal activities against four phytopathogenic fungi except for *Colletotrichum gloeosporioides*. The essential oil of *Thymus vulgaris* suppressed the mycelial growth of *C. gloeosporioides, Fusarium oxysporum* and *Rhizoctonia solani* and that of *Cymbopogon citratus* was active to only *F. oxysporum*. The chemical compositions of the five active essential oils were determined by gas chromatography-mass spectrometry. Hence *E. citriodora* and *C. cyminum* oils have a potential as antifungal preservatives for the control of storage diseases of various crops.[3][4]

Fungal contamination of indoor air is an issue of increasing public health concern. Essential oils have been demonstrated to have antifungal capabilities, but there are limited studies investigating the efficacy of essential oils against fungi relevant to air quality. This study provides a preliminary screening of the antifungal properties of clove, lavender and eucalyptus essential oils against a range of fungal species isolated from environmental air samples. The ability of the essential oils to inhibit fungal growth was examined using the disk diffusion assay on malt extract agar and was compared with vinegar, bleach and limonene, with phenol as a positive control. [5][6][7]Results identified essential oils which demonstrated antifungal potential against species of environmental origin. Clove oil was found to be most efficacious, with eucalyptus and lavender oils showing some antifungal potential albeit less broad spectrum and with less persistence over time in this assay. All essentials oils performed better than traditional cleaning compounds such as vinegar. Clove oil would be a suitable candidate for further research to validate its use in improving indoor air quality. [8]

In another research, the composition of the essential oil of *Eugenia caryophyllata* and its antifungal activity on *Candida albicans*, *Aspergillus niger* and *Aspergillus flavus* fungal strains were studied in Iran. Essential oil from the flowers parts of the plant was obtained by hydrodistillation and analysed by GC and GC-MS. The oil showed high contents of Eugenol, B-caryophyllene and Euggenyl acetate. The MIC was used to evaluate the antifungal activity against *Candida albicans* ATCC 10231, *Aspergillus niger* ATCC 9642 and *Aspergillus flavus* ATCC 9643. [9][10][11]Antifungal activity was evaluated for the essential oil and simultaneously for Amphotricin B. Results showed that *Eugenia caryophyllata* essential oil exhibited a significant activity against fungi, and its MIC on *Candida albicans, Aspergillus niger* and *Aspergillus flavus* were respectively 0.50, 0.125 and 0.25 μg ml-1 (ppm).The present study indicates that *Eugenia caryophyllata* essential oil has considerable antifungal activity, deserving further investigation for clinical applications.[12][13]

Discussion

The most commonly used essential oils with antifungal action are: β-caryophyllene, eugenol, eugenol acetate, carvacrol, linalool, thymol, geraniol, geranyl acetate, bicyclogermacrene, cinnamaldehyde, geranial, neral, 1,8-cineole, methyl chavicol, methyl cinnamate, methyl eugenol, camphor, α-thujone, viridiflorol, limonene, (Z)-linalool oxide, α-pinene, p-cymene, (E)-caryophyllene, γ-terpinene. Some essential oils are effective antifungals and have been evaluated for food incorporation in vitro. However, actual deployment is rare because much higher concentrations are required in real foods. Some or all of this lower effectiveness is due to large differences between culture medium and foods in: chemistry (especially lipid content), viscosity, and duration of inoculation/storage.[14][15]

Fungicides are biocidal chemical compounds or biological organisms used to kill parasitic fungi or their spores.[1] A fungistatic inhibits their growth. Fungi can cause serious damage in agriculture, resulting in critical losses of yield, quality, and profit. Fungicides are used both in agriculture and to fight fungal infections in animals. Chemicals used to control oomycetes, which are not fungi, are also referred to as fungicides, as oomycetes use the same mechanisms as fungi to infect plants.[2] Fungicides can either be contact, translaminar or systemic. Contact fungicides are not taken up into the plant tissue and protect only the plant where the spray is deposited. Translaminar fungicides redistribute the fungicide from the upper [16][17], sprayed leaf surface to the lower, unsprayed surface. Systemic fungicides are taken up and redistributed through the xylem vessels. Few fungicides move to all parts of a plant. Some are locally systemic, and some move upwardly.[3] Most fungicides that can be bought retail are sold in a liquid form. A very common active ingredient is sulfur,[4] present at 0.08% in weaker concentrates, and as high as 0.5% for more potent fungicides. Fungicides in powdered form are usually around 90% sulfur and are very toxic. Other active ingredients in fungicides include neem oil, rosemary oil, jojoba oil, and the beneficial fungus *Ulocladium oudemansii*.[18][19]

Fungicide residues have been found on food for human consumption, mostly from post-harvest treatments.[5] Some fungicides are dangerous to human health, such as vinclozolin, which has now been removed from use.[6] Ziram is also a fungicide that is toxic to humans with long-term exposure, and fatal if ingested.[7] A number of fungicides are also used in human health care.

The essential oils of aegle, ageratum, citronella, eucalyptus, geranium, lemongrass, orange, palmarosa, patchouli and peppermint, were tested for antibacterial activity against 22 fungi including (3 yeast-like and 19 filamentous) by the disc diffusion method. Lemongrass, eucalyptus, peppermint and orange oils were effective against all the 22 fungal strains. *Aegle* and palmarosa oils inhibited 21 fungi; patchouli and ageratum oils inhibited 20 fungi and citronella and geranium oils were inhibitory to 15 and 12 fungal strains, respectively. All fungi were inhibited by seven oils (aegle, citronella, geranium, lemongrass, orange, palmarosa and patchouli). Eucalyptus and peppermint oils were effective against eleven fungi. *Ageratum* oil was inhibitory to only four fungi tested.[20][21]

Results

Patchouli oil is an essential oil derived from the leaves of the patchouli plant, a type of aromatic herb.In order to produce patchouli oil, the leaves and stems of the plant are harvested and allowed to dry out. They then undergo a distillation process to extract the essential oil. Patchouli oil has a characteristic scent that might be described as woody, sweet, and spicy. Because of this, it’s often used as a scent additive in products like perfumes, cosmetics, and incense.Patchouli oil has a variety of additional uses throughout the world. Some of these include: treating skin conditions such as dermatitis, acne, or dry, cracked skin,easing symptoms of conditions like colds, headaches, and stomach upset, relieving depression, providing feelings of relaxation and helping to ease stress or anxiety, helping with oily hair or dandruff, controlling appetite, using as an insecticide, antifungal, or antibacterial agent, using as an additive in low concentrations to flavor foods like candies, baked goods, and beverages. [22]A recent study looked at the antifungal activity of 60 essential oils against three species of disease-causing fungus: *Aspergillus niger*, *Cryptococcus neoformans*, and *Candida albicans*. It was found that patchouli oil had noteworthy antifungal activity against *C. neoformans*. Antifungal activity was also observed for *A. niger*. An effectiveness of tea tree oil highlights its ability to kill a range of yeasts and fungi. The majority of the studies reviewed focus on *Candida albicans*, a type of yeast which commonly affects the skin, genitals, throat, and mouth. Other research suggests suggests that terpinen-4-ol enhances the activity of fluconazole, a common antifungal drug, in cases of resistant strains of *Candida albicans*.[23] *Rosa damascena* petals were extracted by water, hexane and ethanol. The latter was further fractionated with chloroform, ethyl acetate and butanol. Rose oil and different petal extracts were evaluated against three fungi .Rose oil and all extracts exerted antifungal activities against the tested organisms. The descending order of antifungal activity of rose oil and different extracts was, *Penicillium notatum*, *Aspergillus niger* and *Candida albicans*. Ethyl acetate extracted fraction was relatively more active against the tested bacteria than the other tested extracts. [24] The essential oil from the powder residual of dried bitter almond, a novel and environmentally-friendly fungicide, was successfully extracted in a 0.7% yield by hydro-distillation under optimized conditions.[25]

Table: Antifungal effects of several essential oils

Essential Oil	Major Compounds	Pathogens Tested	MIC/Concentration Used in the Studies	Converted Values (µg/mL)	Number of Strains Tested	% of the Major Compound (When Presided)
Thymus vulgaris	Thymol Carvacrol p-Cymene	*Candida albicans*	62 µg/mL		1	Thymol 60.8% Carvacrol 2.88% p-Cymene 15.4%
		Candida tropicalis				
		Fusarium sp	ED50 71 µg/mL		1	Thymol 0.2% Carvacrol 81.5%
		Aspergillus sp	9.85 µg/mL		44	Thymol 33% Carvacrol 3.9%
		Penicillium sp	19.17 µg/mL		18	
		Cladosporum sp	15.20 µg/mL		6	
		Botrytis cinerea	-		1	-
		Alternaria brassicae	ED50 67.7% *v/v*	ED50 677 µg/mL	1	-
		Fusarium oxysporum	ED50 36.3% *v/v*	ED50 363 µg/mL	1	
Thymus pulegioides		*Fusarium graminearum*	105–108 µg/mL		1	-
		Aspergillus sp	0.16–0.64 µL/mL	160-–40 µg/mL	9	Thymol 26% Carvacrol 21%
		Dermatophytes			5	
		Candida sp			11	
Maleleuca alternifolia	Terpinen-4-ol	*Aspergillus* sp	0.016%–0.12% *v/v*	1.6–200 µg/mL		Terpinen-4-ol 40.1%
		Candida sp	0.03%–8% *v/v*	3–800 µg/mL		
		Candida albicans	1.95 mg/mL		1	-
Origanum vulgare	Thymol Carvacrol Sabinene Linalool	*Botrytis cinerea*	ED50 50 µg/mL		1	Thymol 63.7% Carvacrol 8.6%
		Fusarium sp			1	
		C. albicans	1.48–1.75 mg/mL		1	Carvacrol 39.08%–49.03% Sabinene 1 9.81%–25.11%
		A. niger	2.75–2.85 mg/mL		1	
		C. glabrata	0.5–1100 µg/mL		16	Thymol 25.1% Linalool 42%
		A. flavus	400 ppm	3.6 ug/mL	1	
Mentha piperita	Linalool Menthol Piperitone	*Candida albicans*	1 µL/mL	1 mg/mL	1	Piperitone 38% Piperitenone 33%
		Aspergillus niger	0.25 µL/m	250 mg/mL	1	
		Candida sp	800 µg/mL			-
		Aspergillus sp	222 µg/mL			
Mentha	Pulegone	*Candida albicans*	500 ppm	44.5 µg/mL	1	Menthol 37.88%

Essential Oil	Major Compounds	Pathogens Tested	MIC/Concentration Used in the Studies	Converted Values (µg/mL)	Number of Strains Tested	% of the Major Compound (When Presided)
pulegium		*Candida* sp	400–7000 µg/mL			-
		Dermatophyte	800–3500 µg/mL			
		Aspergillus sp	400–3500 µg/mL			
Lavendula angustifolia	Linalool Linalyl acetate	*b.cinerea*	ED50 223 µg/mL		1	Linalool 25.5% Linalyl acetate 17.7%
		Fusarium sp	520 µg/mL		1	
		F.oxysporum	ED50 372 µL/mL	37.2 mg/mL	1	-
		C. albicans	1/40 of pure solution of essential oil		20	-
		C. albicans	5000 ppm	445 µg/mL	50	Linalool 24.7% Linalyl acetate 31.1%
Rosmarinus officinialis	1,8-Cineole Camphor α-pinene	*B.cinierea*	ED50 600 µg/mL		1	Eucalyptol 31.5%
		Fusarium sp	660 µg/mL		1	
		C. albicans	MIC 80% 24–31 µg/mL		11	1,8-Cineole 31.5%
		C. albicans	0.78 mg/mL		1	1,8-Cineole 52.2% Camphor 15.2% α-pinene 12.4%
Pelargonium graveolens	(Z)-geraniol Citronellol	*C. albicans*	0.16% *v/v*	1.6 mg/mL	47	Citronellol 11.94%
		C. glabrata			20	
		C. albicans	500–1000 µg/mL		5	Citronellol 27.23%
		C. tropicalis	250 µg/mL		1	
		C. parasilopsisi	500 µg/mL		1	
		C. glabrata	500 µg/mL		2	
		C. riferi	500 µg/mL		1	
Eucalyptus citriodora	Citronellol Citronellal	*C. albicans*	318 µg/mL		1	-
Eucalyptus camaldulensis	p-cymene 1,8-Cineole	*P. funicuarum*	0.15 mg/mL			-
		A. niger	0.47 mg/mL			
		A. flavus	0.43 mg/mL			
Cinnamomum verum	Cinnamaldehyde	*Fusarium*	31.25–500 µg/mL		18	Cinnamaldehyde 93.1%
		A. flavus	100 ppm	8.9 µg/mL	1	-
		C. albicans	31.25–62.5 µg/mL		5	Cinnamaldehyde 82.09%
		C. parasilopsis			1	
		C. riferii			1	
		C. tropicalis			1	
		C. glabrata			2	
Cuminum	Cuminaldehyde	*Fusarium* sp	0.6 µL/mL	600 µg/mL	1230	Cymene

Essential Oil	Major Compounds	Pathogens Tested	MIC/Concentration Used in the Studies	Converted Values (μg/mL)	Number of Strains Tested	% of the Major Compound (When Presided)
cyminum	Cymene γ-terpinene 1,8-cineole	*Aspergillus* sp				47.8% Cuminaldehyde 14.92% γ-terpinene 19.36%
		C. albicans	3.90–11.71 μg/mL		20	1,8-cineole 21.07%
Sysygium aromaticum	1,8-cineole Eugenol	*C. albicans*	MIC 50% 6.2–7.5 μL/mL	6.2–7.5 mg/mL	38	Eugenol 76.84%
		A. brassicae	ED50 54% *v/v*	540 μg/mL	1	Eugenol 86.38%
		F.oxysporum	ED50 44.7% *v/v*	447 μg/mL	1	
		C. albicans	125–250 μg/mL		5	Eugenol 90.43%
		C. parapsilopsis			1	
		C. riferii			1	
		C. tropicalis			1	
		C. glabrata			2	

The chemical composition of bitter almond essential oil (BAEO) was analyzed by gas chromatography-mass spectrometry (GC-MS). Twenty-one different components representing 99.90% of the total essential oil were identified, of which benzaldehyde (62.52%), benzoic acid (14.80%), and hexadecane (3.97%) were the most abundant components.[20][21] Furthermore, the in vitro and in vivo antifungal activities of BAEO against common plant pathogenic fungi were evaluated by the mycelium linear growth rate method and pot test, respectively. It was documented that 1 mg/mL of BAEO could variously inhibit all tested pathogenic fungi with the inhibition rates of 44.8%~100%. Among the tested 19 strains of fungi, the median effective concentration (EC50) values of BAEO against *Alternaria brassicae* and *Alternaria solani* were only 50.2 and 103.2 μg/mL, respectively, which were higher than those of other fungi. The in vivo antifungal activity of BAEO against *Gloeosporium orbiculare* was much higher than *Blumeria graminis*. The protective efficacy for the former was up to 98.07% at 10 mg/mL and the treatment efficacy was 93.41% at 12 mg/mL. The above results indicated that BAEO has the great potential to be developed as a botanical and agricultural fungicide.[22]

Conclusions

Thyme essential oil (*Thymus vulgaris*) is already known to be effective against fungi infecting humans. Its antifungal activity is due to its high concentration of thymol and carvacrol [20]. It has been demonstrated an inhibition of *Candida albicans* and *Candida tropicalis* with *Thymus vulgaris* essential oil and these major constituents at 62 μg/mL. Daferera et al. showed an activity on *Fusarium* spp with an ED50 (dose of essential oil that inhibits 50% of mycelium) at 71 μg/mL [21]. Finally, a study by Klarić et al. showed that molds such as *Aspergillus* spp, *Penicillium* spp and *Cladosporium* spp could be completely inhibited with a thyme oil concentration of 9.85, 19.17 and 15.20 μg/mL, respectively.[22][23] First known in aromatherapy for its relaxing and sedative virtues, lavender essential oil (*Lavandula angustifolia*) is now studied for its effectiveness against microorganisms, including fungi. [24]There is an effectiveness of *Eucalyptus camaldulensis* oil against various pathogenic fungi including *Penicillium funiculosum*, *Aspergillus niger* and *Aspergillus flavus*.[25]

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