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Review article

Antibiofilm activity of essential oils in *Candida* spp. : A literature review

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Abstract

Species of the genus *Candida*, despite part of the normal human microbiota, can cause important fungal infections ranging from superficial clinical manifestations to fatal invasive lesions. Most of these infections are related to the ability of *Candida* spp. To form biofilm, which results in increased resistance to antifungal agents, such as ketoconazole, amphotericin B and fluconazole, hindering proper treatment. The increase in these infections together with increased resistance to antifungal drugs has made it necessary to seek new therapeutic alternatives. Among the new alternatives is the search for essential oils of plants that have antibiofilm properties. A search was performed in the Science direct, Scopus, PubMed and Scielo databases. From this search, a total of 39 essential oils were found, related to antibiofilm activity in front of *Candida* species, among them are lemon grass, eucalyptus, cinnamon and tea tree oils. The data found in this review demonstrated the antibiofilm activity of most essential oils, suggesting that they can be used as new treatment alternatives and reinforcing the need for further studies to prove their efficacy.

Introduction

Candidiasis is one of the main causes of opportunistic fungal infections. The factors that imply the increased occurrence of candidiasis are immunosuppressive therapies, invasive surgical procedures and the use of broad-spectrum antimicrobials [1, 2]. *Candida* species infections range from mucosal colonization to invasive lesions that can be fatal [1]. *Candida albicans* is the most frequent fungal species and cause superficial, cutaneous, subcutaneous and systemic infections [3]. However, other species known as "non-albicans", including *Candida tropicalis, C. glabrata, C. parapsilosis* and others have been isolated regularly [4].

Candida species are found both in the environment and in the normal flora of humans, so their presence in the organism will not always indicate fungal infection. They are causatous agents that can reach high mortality rates, especially in immunocompromised individuals, intensive care patients, post-surgical units and neoplasms [3, 5]. *Candida* species can colonize and cause diseases in various sites of the body such as the skin, oral cavity, gastrointestinal tract, genital, vascular system and others [5, 6].
The pathogenesis of candidiasis depends on the health of the host, as well as the virulence factors that these species express in certain situations. Virulence factors include germ tube formation, adhesin production, adhesions, biofilm formation and hydrolytic enzyme production [3, 6].

The expression of virulence factors may vary depending on the infecting species, geographic origin, type of infection, location and stage of infection, and host reaction. Knowledge of these factors is considered an important tool to understand the pathogenesis of fungal diseases caused by *Candida* spp. and to assist in the development and discovery of new therapeutic targets [7].

Most diseases caused by *Candida* species are related to biofilm formation [3]. Biofilm production varies according to *Candida* species and consists of a pathogenetic factor that plays an important role in tissue adhering and colonization by *Candida* spp. [8]. The biofilm corresponds to a group of microorganisms embedded in an extracellular matrix that form a three-dimensional structure on biotic and abiotic surfaces [6, 9]. Microbial biofilms are the main cause of hospital infections and the source of many diseases that become recurrent and persistent. In addition to biofilms being genetically resistant to some antifungals, including amphotericin B and fluconazole, studies show that biofilms of *Candida* species considerably reduce sensitivity to different antifungals, hindering their treatment [3, 4, 6].

The increased resistance of these pathogens to conventional antifungals as well as their side effects, such as nausea, vomiting, rash and others, encouraged the search for new therapeutic alternatives. There has been a growing interest in the study of secondary metabolites of plants as new therapeutic alternatives, especially essential oils, as they have antibacterial and antifungal properties [10, 11].

Essential oils (OEs) are natural compounds constituted of a complex mixture of volatile compounds extracted from medicinal and aromatic plants with promising biological properties [10, 12]. They have wide application in popular medicine, aromatization, food preservation and fragrance industries. In recent years, studies have shown that essential oils and their constituents have antimicrobial properties against some bacteria and fungi. However, there are still few studies on the action of essential oils against the biofilm formed by *Candida* spp. [13, 10].

In view of the need for new therapeutic alternatives for the treatment of infections caused by *Candida* spp. and, the use of essential oils from plants with antibiofilm activity appears as a promising therapeutic alternative. Thus, the objective of the present study was to conduct a literature review on the antibiofilm activity of some essential oils against *Candida* spp.

A literature review was carried out in the online databases Science direct, Scopus, PubMed and Scielo. Scientific articles related to essential oils from plants with antibiofilm activity against *Candida* spp were searched. The keywords used were *Candida* spp. AND oil AND antibiofilm for the last 10 years (2010 to 2020).

In this research 279 articles were found in Science direct, 48 in Scopus, 40 in PubMed and 3 articles in Scielo. These articles were analyzed in their entirety to verify the relevance for the purpose of this review. After reading and excluding articles not truly related to the purpose of this study, a total 31 articles of oils were found associated with the antibiofilm activity of *Candida albicans*, *C. tropicalis, C. krusei, C. dublinienses, C. glabrata, C. parapsilosis, C. guillermondii, C. rugosa, C. lusitaniae*, *C. membranafaciens C. famata, C.boidinii, C. pelliculosae C. colliculosa* (Table 1).

Essential oils with antibiofilm activity for *Candida* spp.

In the last 10 years, few studies have been done on the effectiveness of essential oils in inhibiting the biofilm formation of *Candida* species. The main results obtained from the antibiofilm activity of essential oils found in *Candida* species are listed below:

Essential oil of *Anthemis stiparum*

Elkhalifa e*t al.* analyzed the antibiofilm activity of essential oil and methanolic extract of *Anthemis stiparum* on *Candida albicans* and other microorganisms. The essential oil of *Anthemis stiparum* showed moderate antibiofilm activity against *C. albicans* ATCC 10239 in the MIC (50 µL/mL). The methanolic extract demonstrated greater antibiofilm activity against *C. albicans*, inducing 80.02% biofilm inhibition when used tested by the MIC [14].

Essential oil of *Aeollanthus cucullathus, Aeollanthus heliotropioides* and *Plectranthus glandulosus*

Mback *et al.* evaluated the antibiofilm activity of the essential oils of *Aeollanthus cucullathus, Aeollanthus heliotropioides* and *Plectranthus glandulosus* against the species of *Candida albicans* and *C. glabrata*. The results obtained demonstrated that there was inhibition of the mature biofilm at the tested concentrations (MIC/2; MIC/4; MIC/6, MIC/10), 0.06 mg/mL, 0.5 mg/mL, 3 mg/mL, respectively. The best result was obtained by the essential oil of *A. helitropioides* followed by the essential oil of *P. glandulosus* and *A. cucullathus* [15].

Essential oil of *Melaleuca alternifolia* (tea tree)

Francisconi *et al.* tested and demonstrated antibiofilm activity of tea tree oil and its main component terpinen-4-ol against two clinical strains of *Candida albicans*. These strains, identified by molecular typing as genotypes A and B, were isolated from diabetic patients with chronic periodontitis. Nystatin tests using the reference strains *C. albicans* ATCC 90028 and SC 5314 were also compared to the results. Mouthwash simulations containing the oil, terpinen-4-ol and nystatin were also performed. The researchers also observed that at concentrations of 17.92 mg/mL for tea tree oil and 8.86 mg/mL of terpinen-4-ol, both were effective against the biofilm formed in the samples when compared to treatment with nystatin. In addition, it was possible to observe that there was less antibiofilm effect of the oil and its main component against the strain of *Candida albicans* genotype A [16].

Table 1. Essential oils studied for antibiofilm activity against *Candida* species.

Oils found	Cited *Candida* species													
Aeollanthhus cucullathus	C1				C5									
Aeollanthus heliotropioides	C1				C5									
Anthemis stiparum	C1													
Cedrela fissilis	C1													
Cinnamomum camphora	C1	C2			C5									
Cinnamomum tamala	C1	C2			C5									
Cinnamomum verum	C1	C2			C5									
Citrus hystrix	C1		C3											
Citrus x limon		C2												
Cymbopogon citratus	C1	C2	C3	C4										
Cymbopogon flexuosus	C1													
Cymbopogon winterianus	C1		C3											
Cuminum cyminum	C1	C2												
Eucalypthos globulus	C1	C2			C5									
Gaultheria procumbens L.	C1													
Hedychium coccineum	C1													
Longifolia mint	C1													
Lavandula augustifolia	C1													
Laurus nobilis	C1	C2	C3		C5									
Mint x piperita L.	C1	C2	C3	C4	C5	C6								
Melaleuca alternifólia	C1	C2			C5	C6								
Ocimum basil	C1		C3											
Ocimum tenuiflorum	C1		C3											
Pelargonium graveolens	C1	C2	C3		C5									
Plectranthus glandulosus	C1				C5									
Pogostemon heyneanus	C1	C2			C5									
Sage triloba L.	C1													
Satureja macrosiphon	C1			C4										
Satureja hortensis L.	C1													
Syzygium aromaticum	C1	C2	C3			C6		C8	C9	C10	C11	C12	C13	C14
Thymbra capitata	C1	C2			C5	C6	C7							
Thymus capitatus	C1													
Thymus vulgaris	C1	C2	C3			C6		C8	C9	C10	C11	C12	C13	C14
Turmeric longa L.	C1		C3											
Zingiber cassumunar	C1		C3											
Zingiber officinale	C1		C3											
Ziziphora Tenuior	C1													

C1 - *Candida albicans*; C2 - *Candida tropicalis*; C3 - *Candia krusei*; C4 - *Candida dubliniensis*; C5 - *Candida glabrata*; C6 - *Candida parapsilosis*; C7 - *Candida guillermondii*; C8 - *Candida rugosa*; C9 - *Candida lusitaniae*; C10 - *Candida famata*; C11 - *Candida boidinii*; C12 - *Candida pelliculosa*; C13 - *Candida colliculosa*; C14 - *Candida membranafaciens*.

Souza *et al.* tested the antibiofilm activity of tea tree essential oil and nanoparticles of tea tree oil to reduce problems due to the low solubility and high volatility that this oil presents. Both were tested for action on biofilms formed by *C. albicans, C. glabrata, C. tropicalis, C. parapsilosis* and *C. membranafaciens*. The essential oil of tea tree showed a significant reduction in the biomass of the biofilm formed when compared to the positive control in all tested strains. The best result was obtained against *C. glabrata*, both for oil and for nanoparticles. It was also observed that at the same concentration, nanoparticles show a greater reduction in biofilm formation compared to *Candida* species [17].

Essential oil of *Cymbopogon* sp.

Khan and Ahmad evaluated the antibiofilm activity of essential oil of *Cymbopogon citrates* (lemongrass) against *Candida albicans* at concentrations of 1/2 MIC and 1/4 MIC and obtained a reduction of 11.46 to 24.67% [18]. In the study of Sahal *et al.* the antibiofilm activity of lemon grass oil in three strains of *Candida tropicalis*. The results showed inhibition in the formation of biofilms in the three strains of *Candida tropicalis* tested at concentrations of 0, 2, 4 and 8% (w/w) [19]. Ngo-Mback *et al.* tested the antibiofilm activity of lemongrass essential oil in front of *Candida glabrata*. The oil was fractionated by silica gel chromatography in order to find the most active compounds. The results showed that the combination of the F7F10 fractions of lemongrass oil inhibited the formation of *Candida glabrata* biofilm in the

dose-dependent form. A 30% decrease in biofilm formation was observed when compared to the control at a MIC/10 concentration [21].

Taweechaisupapong *et al.* tested the antibiofilm activity of lemon grass oil in biofilm formation and against preformed biofilm of *Candida dubliniensis*. At the same time, the same tests were also performed for nystatin. The results revealed that the inhibiting effect of lemongrass and nystatin oil is related to doses. Lemongrass oil was tested at concentrations between 0.11 and 27.6 mg/mL and exhibited 40 to 99% inhibition in biofilm formation. Nystatin at concentrations between 4 and 512 µg/mL and exhibited 20-93% inhibition in biofilm formation. Regarding antibiofilm activity in relation to the preformed biofilm of *Candida dubliniensis*, both lemongrass oil and nystatin were less efficient, in the same concentrations [13]. In another study by the same author was evaluated the antibiofilm activity of lemongrass essential oil against *Candida albicans* and *C. krusei*. The results revealed that the inhibiting effect of oils on biofilm formation and against preformed biofilm was dose-related. The essential oil of lemongrass showed inhibition in the formation of biofilm in *Candida* spp isolates, being higher for *Candida krusei* than in *Candida albicans*. In addition, it was observed that lemongrass oil and its main constituents were able to reduce the adhesion of *Candida* cells used [21].

Da Silva *et al.* evaluated the antibiofilm activity of lemongrass essential oil in front of *Candida albicans* biofilm simulating mouthwash applications to evaluate the best action of the oil as to inhibition of formation, biofilm removal or in both situations. This study aimed at a further development of mouthwash based on lemongrass oil. The results showed that there was inhibition in the formation of the biofilm of *Candida albicans,* however, there was no effect on the removal of the mature biofilm by the strains used [22].

Cymbopogon flexuosus essential oil (Indian lemongrass) was evaluated in the study developed by da Silva Gundel *et al.* This study verifies the antibiofilm activity of *C. flexuosus* (Indian lemongrass) free and nanoemulsion in front of the *Candida albicans* biofilm and other micro-organisms of interest. As a result, it was observed that the formation of the biofilm of *C. albicans* was inhibited at concentrations of 1.22 mg/mL and 2.56 mg/mL for free oil and at concentrations of 0.28 mg/mL and 0.58 mg/mL for nanoemulsion This result indicates that the nanoemulsion containing the oil has higher antibiofilm activity than the free oil against *C. albicans*. Further studies should be conducted to prove its effectiveness [23].

Cymbopogon winterianus (citronella) essential oil showed antibiofilm activity against *Candida albicans* isolates at concentrations of 5 and 10 MIC. The best results were in the inhibition of biofilm formation. For the biofilm of *C. albicans*, the lowest microbial counts were obtained in citronella oil concentration 10 MIC. The commercial mouthwashes tested showed lower antibiofilm activity in relation to citronella essential oil [24].

Essential oil of *Thymus capitatus* (Thyme)

Essid *et al.* analyzed the antibiofilm activity of the essential oil *Thymus capitatus* and their combined effect with amphotericin B and nystatin. The results showed that the essential oil of *T. capitatus* significantly inhibited the formation of the biofilm of *C. albicans*. The thyme essential oil at ½ MIC (62.5µg/mL) the inhibition in biofilm formation of *C. albicans* was 80.6%, In comparison, at 1/2 MIC, essential oils had a higher inhibiting effect than amphotericin B and nystatin. It was also observed that the combination of the essential oil of *T. capitatus* with amphotericin B or nystatin showed a significant increase in antibiofilm activity. Both oils showed great eradication activity of preformed biofilm at concentrations twice as high as inhibition in biofilm formation. In addition, the combination of essential oils with antifungal was used in an in vitro biofilm model of *C. albicans* associated with a venous catheter. The combinations showed almost complete rupture of the biofilm on the catheter surface, demonstrating synergistic effect between the oils and antifungal agents tested [25]. In another study with thyme oil, total inhibition of biofilm development was observed for *C. tropicalis, C. pelliculosa*and *C. albicans* strains in polypropylene and glass. Only a few strains of *C. colliculosa* and *C. parapsilosis* were resistant to thyme oil at the concentrations used [26].

Jafri; Ahmad evaluated the antibiofilm activity of thymus vulgaris essential oil and its main component, thymol, in *Candida albicans* and *C. tropicalis* isolates. These were evaluated for biofilm inhibition and eradication of preformed biofilm at different concentrations, including sub-inhibition concentrations. The variable level of attenuation of the biofilms of *C. albicans* and *C. tropicalis* obtained in the presence of *T. vulgaris* and timol indicated that there was inhibition of the biofilm, preventing adhesion and its development [27].

Alves *et al.* evaluated the ability of the essential oils of *Thymus carnosus and T. camphoratus* to decrease the mass and viability of the *Candida albicans* biofilm. As a result, both oils were effective at concentrations close to their MIC, and the essential oil of *T. carnosus* was slightly more active in reducing the viability of the biofilm [28].

Essential oil of *Syzygium aromaticum* (Clove)

Rajkowska *et al.* reported the antibiofilm activity of clove essential oils in different strains of *C.albicans, C. krusei, C. lusitaniae, C. rugosa, C. tropicalis, C. parapsilosis, C. famata, C. boidinii, C. pelliculosa and C. colliculosa*. The results showed that the essential clove oil at MIC resulted in the total inhibition of the biofilm formation of the strains of *C. lusitaniae, C. krusei, C. tropicalis, C. rugosa* and *C. albicans* on glass surface and polypropylene (PP). On polyethylene terophalate (PET) surface, clove oil completely inhibited the biofilm formation of the strains of *C. lusitaniae, C. boidinii, C. tropicalis, C. rugosa,* and *C. albicans*. Only three isolates, one strain of *C. krusei, C. parapsilosis* and *C.*

pelliculosa, showed resistance to clove oil in the tested materials. Biofilms not completely inhibited by clove oil were significantly reduced in the materials analyzed [26]. In the study by Khan and Ahmad, clove oil at the concentration of 1/2 MIC inhibited 50% of *Candida albicans* biofilm formation [18].

Essential oil of *Juniperus virginiana* (Cedar)

Manoharan *et al.* evaluated the antibiofilm activity of the essential oil of cedar leaves and their main components against *Candida albicans*. The result shows that the essential oil of the cedar leaf inhibited, in a dose-dependent manner, the formation of the biofilm of *C. albicans* in 87% at a concentration of 0.01%. The components examined at concentrations of 0.01% significantly inhibited the formation of the biofilm. In addition, the metabolic activity of biofilm cells and their adherence were reduced [29].

Essential oil of*Eucalyptus globulus* (eucalyptus)

Quatrin *et al.* analyzed the antibiofilm activity of eucalyptus essential oil by comparing the activity of free oil and the nanoemulsion containing the oil against isolates of *Candida albicans, C. tropicalis* and *C. glabrata*. The results obtained proved the antibiofilm activity of eucalyptus oil. In the comparison of the forms presented, it was observed that there were no significant difference between the activity of eucalyptus essential oil and their nanoemulsion against *C. albicans, C. tropicalis* and *C. glabrata*, since the variations found in the tests were the same between the species [30].

Essential oil of *Gaultheria procumbens* L. (Wintergreen)

Nikolic *et al.* tested the antibiofilm activity of the essential oil of *Gaultheria procumbens* L. against the biofilm of *Candida albicans* and *Streptococcus mutans*. For this, they used the essential oil of *Gautheria procumbens* L., Hexoral® and Tebodont®, (mouthwashes). It was observed that Hexoral® and Gaultheria procumbens oil showed good antibiofilm activity, and Hexoral ® most effective. It is suggested that the antibiofilm activity of mouthwashes is due to the presence of its components, especially methyl salicylate, which is the main component of essential oil of *Gaultheria procumbens* L. Further studies are needed to prove such antibiofilm activity [31].

Essential oil of *Laurusnobilis* (Bay)

Peixoto et al.analyzed the inhibition of adhesion, biofilm formation and reduction of mature biofilm of *Candida albicans* by bay essential oil. The results showed that essential oil of *L. nobilis* inhibited the initial adhesion of *C. albicans* at 1000µg/mL (2 MIC). At the tested concentrations (MIC, 2 MIC and 4 MIC), the essential oil inhibited the formation of the biofilm. In addition, when the oil was applied for 1 min every 8h, for 24h and 48h, a decrease in mature biofilm of *Candida albicans* was observed. There was no significant difference when compared to nystatin. This indicates that essential oil may be a treatment alternative for *Candida* spp infections however, more studies should be carried out [10].

Essential oil of *Mentha* sp.

Pazarci and Tutar analyzed the antibiofilm activity of *Mentha longifólia* (wild mint) against *Candida albicans* and others biofilm-producing microorganisms *in vitro* implant surfaces. The surfaces tested were titanium and stainless steel, which showed no variation in biofilm growth. The results obtained showed good inhibition in the formation of biofilm, mainly of *C. albicans* which was susceptible to *M. longifolia* oil. In the highest concentrations of oil, a better eradication of the biofilm was observed, which may demonstrate that the antibiofilm activity is related to the dose of the applied oil. In addition, differences were observed in relation to the eradication of biofilm on titanium and stainless-steel surfaces at the different concentrations of essential oil used [32].

Saharkhiz *et al.* evaluated the antibiofilm activity of essential oil of *Mentha piperita* L. (peppermint) against *Candida albicans* and *C. dubliniensis*. Peppermint essential oil completely inhibited the biofilm formation of *C. albicans* and *C. dubliniensis* in a dose-dependent form at concentrations of 1 µL/mL and 2 µL/mL, respectively [33].

Essential oil of *Pelargonium graveolens* (Geranium)

Giongo *et al.* evaluated the antibiofilm activity of the essential oil of *Pelargonium graveolens* and its nanoemulsion against *Candida* species. The geranium essential oil and its nanoemulsion inhibited the formation of the biofilm of *C. albicans, C. tropicalis, C. glabrata* and *C. krusei*. The nanoemulsion containing the oil presented better antibiofilm activity for *C. albicans* and *C. krusei* when compared to the action of the essential oil. Against *C. glabrata* and *C. tropicalis* was not difference, both, the nanoemulsion and the essential oil have a similar antibiofilm activity. When tested on catheters containing biofilm formed from the *Candida* species, the nanoemulsion containing the oil significantly increased activity in all species, when compared to the control of biofilm formation. In addition, in the presence of oil and nanoemulsion, a reduction in protein was observed, which is used as a measure of biofilm biomass, in plates and catheters, confirming their antibiofilm activity in the *Candida* species used [34].

Essential oil of *Cinnamomum* sp.

Banu *et al.* tested the inhibition of biofilm formation and the rupture of preformed biofilm of the Essential Oils of *Cinnamomum tamala* (Indian cassia) and *Cinnamomum camphora* (Camphor) against *Candida albicans, C. tropicalis* and *C. glabrata*. All essential oils tested were able to inhibit the biofilm formation of the *Candida* species used and significantly reduced preformed biofilms of *C. albicans, C. tropicalis* and *C. glabrata* in a range of 55-67%. In addition,

it was observed that essential oils reduced cell viability in preformed biofilms [12]. In other study Essid *et al.* analyzed the antibiofilm activity of the essential oils of *Cinnamomum verum* and their combined effect with amphotericin B and nystatin. The results showed that the essential oils of *C. verum* significantly inhibited the formation of the biofilm of *C. albicans*. At ½ MIC (31.25 µg/mL) inhibition in biofilm formation of *C. albicans* was 85.57%. The combination of *C. verum* with amphotericin B and nystatin showed no significant increase in inhibition [25].

Essential oil of *Pogostemon heyneanus* (Patchouli)

Banu *et al.* verified the antibiolme activity of the essential oil of *Pogostemon heyneanus* (patchouli). All essential oils tested were able to inhibit the biofilm of the *Candida* species used. Regarding the preformed biofilm, all three reduced 60% in the biofilm formation of *C. albicans, C. tropicalis* and *C. glabrata*. In addition, it was observed that essential essentials reduced cell viability in preformed biofilms [12].

Essential oil of de *Salvia* sp.

Al-Bakri; Othman and Afifi tested the antifungal activity of seven salvia species *(Salvia ceratophylla L., S. dominica* L., *S. hierosolymitana* Boiss., *S. indica* L., *S. syriaca* L., *S. fruticosa* Mill. [syn. *S. triloba* L.] and *S. verbenaca* L. in *Candida albicans* and other microorganisms. For biofilm inhibition, the essential oil of *S. triloba* L. The essential oil showed good prevention and control of biofilm, presenting anti-adhesion and antibiofilm activities [35].

Essential oil of *Satureja* sp.

Motamedi *et al.* tested the antibiofilm activity of the essential oil of *Satureja macrosiphon* against *Candida albicans* and *C. dubliniensis*. The essential oil showed effective antibiofilm activity against *C. albicans* and *C. dubliniensis* at concentrations of 4 and 8 µg/mL, respectively. It was observed that inhibition was dose-dependent [36].

Sharifzadeh, khosravi and Ahmadian tested the antibiofilm activity of the essential oil of *Satureja hortensis* L. in preformed biofilms of *Candida albicans* isolates from oral lesions of HIV+ patients. The inhibiting effect of essential oil is related to the dose used. At concentrations of 4800, 3200, 2400 and 1600 µg/mL, biofilm formation was reduced on average 87.1%, 73.6%, 69.4% and 67%, respectively. At concentrations below the reduction rate was less than 50%. The decrease in metabolic activity of mature biofilms of *C. albicans* ranged from 7.1 to 80%. The morphology of the biofilm of *C. albicans*, presented morpho structural changes, shrinkage in the cell membranes of sessis cells and the destruction of the three-dimensional structure of the biofilm [37].

Essential oil of *Thymbra capitata*

Palmeira de Oliveira *et al* evaluated the antibiofilm activity of *Thymbra capitata* essential oil in 15 strains of *Candida* spp. (*Candida albicans, C. glabrata, C. tropicalis, C. guilliermondii* and *C. parapsilosis*). The essential oil of *Thymbra capitata* showed an inhibitative effect against *Candida* spp. biofilms. For *C. albicans* and other tested species, the inhibiting effect of biofilm biomass was significant at 2x MIC (0.64 µL/mL).*C. glabrata* was the most resistant to the biomass reduction of the biofilm being less than 50%. However, in relation to the metabolic activity of *C. glabrata* biofilm, a reduction effect of more than 80% was observed at the same concentration, demonstrating that the remaining cells were metabolically inactive or dead. *C. glabrata*, the essential oil when used in *C. albicans* had a higher inhibiting effect for biomass reduction than for metabolism activity. In short, biofilm biomass and metabolic activity were reduced by up to 50% in all species in the MIC value and the most significant effects were observed at 2x MIC [38].

Essential oil of *Zingiber officinale* Roscoe *var rubrum* (Red ginger)

Rinanda *et al.* analyzed the antibiofilm activity of the essential oil of red ginger, whose main components are monoterpenes, on *Candida albicans* isolates for inhibition and degradation of biofilm. The results showed that at the lowest concentration (0.125%) the essential oil has already demonstrated activity in the degradation of the biofilm and this increased with the increase of its concentration. For inhibition in the biofilm formation of *C. albicans* the concentration of red ginger oil found was 0.5%, thus demonstrating that this essential oil showed significant degradation activity and inhibition of *C. albicans* biofilm [39].

Essential oil of *Ziziphora tenuior, Lavandula angustifólia* (lavander) and *Cuminum cyminum* (Cumin)

Dolatabadi, Salari and Mahboubi evaluated the antibiofilm activity of the essential oils of *Ziziphora tenuior, Lavandula angustifólia* and *Cuminum cyminum* against *Candida albicans* isolates of vaginal secretion. The antibiofilm activity of the oils was related to the dose of the applied oil, that is, the highest concentrations used showed greater elimination of the biofilm. The essential oils of *C. cyminume L. angustifolia* showed the greatest elimination effects of *C. albicans* biofilm, followed by the essential oil of *Z. Tenuior* [40].

Conclusion

The search for therapeutic alternatives for the treatment of infections caused by *Candida* species is extremely important, especially when biofilm is formed, resulting in increased resistance to conventional antifungals. The data

found in this literature review demonstrated antibiofilm activity of essential oils, including tea tree oil that showed good antibiofilm activity for *Candida* species and lemongrass oil that considerably inhibited the biofilm formation of *Candida albicans*, suggesting that they can be used as treatment alternatives. Further studies are needed before its use in the therapeutic clinic.

Author contributions

All the authors have contributed equally in designing, drafting the manuscript as per the journal submission format. All authors read and approved the final manuscript.

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