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BASIL, THYME, AND OREGANO ESSENTIAL OILS AS AGENTS FOR COMBATING PHYTOPATHOGENIC FUNGI – A REVIEW

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ABSTRACT

Essential oils are defined as aromatic oily liquids obtained from different parts of plants. They are often responsible for the distinctive smell or taste of a plant. Many of these oils, through their components (carvacrol, thymol, eugenol), exhibit antibacterial and antifungal activity. Being environmentally friendly compounds, they can be successfully used as biopesticides, either individually or in combination. This study is a literature review concerning the chemical composition and antifungal activity of basil, thyme, and oregano oils on phytopathogenic fungi from the genera Aspergillus, Botrytis, Fusarium, and Penicillium.

INTRODUCTION

Plants can release more than 1000 volatile organic compounds consisting mainly of 6-carbon aldehydes, alcohols, esters, and several terpenoids from their different parts (Gobbo-Neto & Lopes, 2007). Any type of volatile oil that has aromatic components in its structure and can provide a distinction in smell or flavor to a plant can be defined as an essential oil. These are practically secondary products of plant metabolism, also known as volatile secondary metabolites of plants. The term "essential oil" is derived from the term Quinta essentia, coined by the Swiss medical reformer Paracelsus von Hohenheim in the 16th century, which means an active component of a medicine. Each of these essential oils can be considered a complex mixture composed of terpenes, phenolic compounds, and phenylpropanoids derived from the acetate-mevalonic and, respectively, shikimic acid pathways. From a horticultural point of view, essential oils represent a new class of crop protection products due to their effects and low environmental toxicity. Cowan (1999) estimates that 3,000 essential oils are known, of which approximately 300 are commercially significant. They are used in agriculture, medicine, and the food industry, among others, due to their antimicrobial, antiviral, insecticidal, and antifungal properties. Fungal diseases in crops alter plant physiology, disrupting their normal functioning, reducing yield, and sometimes causing their death. These molecules have been used for many years as flavoring agents in the preparation of food and cosmetic products, as well as in medicines for therapeutic purposes (Burt, 2004; Hussain et al., 2008; Valgimigli, 2012; Teixeira et al., 2013). Numerous studies aimed to test the antifungal activity of certain essential oils (Kalemba & Kunicka, 2003; Soković and van Griensven, 2006; Koul et al., 2008; Stević et al., 2014), antibacterial activity (Burt, 2004), and antiviral activity (Astani et al., 2011).

MATERIAL AND METHODS

Insoluble in water but soluble in fats, alcohols, organic solvents, and other hydrophobic solutions, essential oils are liquids at room temperature (Thormar, 2011). Finding methods for extracting and recovering the molecules responsible for aroma from plant material has been the subject of numerous studies. Currently, the most common extraction methods are steam distillation and hydrodistillation (Burt, 2004; Lahlou, 2004). In addition to these classical methods, unconventional methods are also used: supercritical fluid extraction (Pourmortazavi and Hajimirsadeghi, 2007), ultrasound (Vinatoru, 2001), and microwave-assisted extraction (Cardoso-Ugarte et al., 2013). Hydrodistillation consists of immersing the plant material in a water bath; the mixture is then heated so that the molecules contained in the plant cells are released in the form of an azeotropic mixture. Although most components have boiling points above 100°C, they are mechanically carried along with the water vapors. Cooling by condensation leads to the separation of the water and oil mixture by decantation. The "Clevenger" system, supported by the European Pharmacopoeia, allows the recycling of the aqueous phase of the distillate. Thus, water and volatile molecules are separated based on their differences in density. The duration of hydrodistillation is generally between three and six hours. A complete characterization of an essential oil involves: sensory evaluation, determination of physicochemical properties, determination of biological properties, and determination of chemical composition. Gas chromatography (GC) is the basic analytical technique used for determining the composition of essential oils.

RESULTS AND DISCUSSIONS

The composition of essential oils

Chemically, essential oils consist of 20-60 components, with the major components present at a relatively high concentration (20-70 %), while the rest are minor components (present in small amounts). Basil (*Ocimum spp*.) and thyme (*Thymus* spp.) belong to the *Lamiaceae* family, which comprises approximately 236 genera and over 6,000 species (Avasiloaiei, D. I., et al., 2023). Basil essential oil consists of a wide and varied range of chemical constituents, depending on the variety, leaf and flower colors, scent, and plant origin (Ghasemi et al., 2013). Methyl chavicol, methyl cinnamate, methyl eugenol, citral, and linalool are the main compounds in basil. Ajmal, M., et al. (2025), while studying the chemical composition of three basil species (*O. basilicum, O. tenuiflorum*, and *O. gratissimum*), found that linalool predominates in *O. basilicum,* methyl chavicol in *O. tenuiflorum*, and eugenol in *O. gratissimum,* noting that the plant material alone cannot be responsible for the different chemical composition. Moghaddam M. et al., (2014,) studied the chemical composition and in vitro antibacterial activity of the essential oil of *O. ciliatum* Hornem. GC and GC-MS analysis showed that the essential oil predominantly contains methyl chavicol, methyl eugenol, and 1,8-cineole, making this plant a good source of methyl chavicol or estragole. However, investigations into the chemical composition of basil essential oil have demonstrated considerable variability (Bernhardt et al., 2015, Telci et al., 2006, Carović-Stanko et al., 2010). Basil has been reported to contain monoterpenoids (carvone, cineole, fenchone, geraniol, linalool, myrcene, and thujone), sesquiterpenoids (caryophyllene and farnesol), a triterpenoid (ursolic acid), and a flavonoid (apigenin) (Ghasemi P.A. et al., 2013). Other authors have noted that basil essential oil contains estragole, linalool, eucalyptol, and bergamotene (Zaharia, 2023).

Furthermore, the compounds involved in the antifungal action of basil essential oil used in these studies are represented by estragol, linalool, eucalyptol, and bergamoten. Thymol, a monoterpene with multiple properties, is the main compound of *Thymus spp.* (thyme) oil - Mrkonjić, et al. 2024. Zaharia, et al., (2023) based on the determinations carried out noted that in the analyzed thyme oil, thymol, o-cymene, γ-terpinene, β-caryophyllene, and limonene predominated. In oregano oil, the major compounds detected were carvacrol and p-cymene (Bounar, R., 2020). Gormez et al., (2015), conducted studies on the composition and antibacterial effect of *Origanum rotundifolium* Boiss. essential oil. The main compounds identified were thymol, carvacrol, p-cymene, and borneol. Kosakowska, O. et al. (2024) found that common thyme and Greek oregano are richer in phenolic monoterpenes and are characterized by stronger antifungal activity than that recorded in common oregano oil. Carvacrol, o-cymene, caryophyllene, terpinenes, limonene, and α-pinene present in oregano oil have demonstrated stronger antifungal activity compared to other compounds present in smaller amounts in this oil (Zaharia R., 2023). Silva, et al. (2025) demonstrated that thymol and carvacrol present in oregano oil exhibited greater antifungal activity compared to eugenol, ρ-cymene, and caryophyllene, which were the main constituents found in the studied basil oil (*Ocimum gratissimum*). The same authors noted that the tested oils exhibited greater antifungal activity compared to antibacterial activity.

It can be concluded that essential oils are mainly composed of two groups of substances: terpenoids (monoterpenes, sesquiterpenes, and diterpenes) and phenylpropanoids. The terpenoid group includes several compounds commonly found in the chemical composition of many plant extracts in varying proportions, such as p-cymene, pinene, limonene, sabinene and terpinen, geraniol, menthol, linalool, citronellol, carvone, thymol, carvacrol, geranyl acetate, eugenyl acetate, geranial, neral, and 1,8-cineole (Nieto, 2017).

The effect of essential oils on phytopathogenic microorganisms

The most studied fungal pathogens in terms of their inhibition by essential oils are: *Aspergillus spp., Botrytis spp., Fusarium spp., Penicillium spp. A. flavus* was inhibited in vitro by basil essential oil, with the best results recorded for *O. tenuiflorum* oil, followed by *O. basilicum* and *O. gratissimum* (Ajmal, M., et al., 2025). *O. basilicum* essential oil inhibited the production of mycotoxins AFB1 and AFG1 produced by A. flavus (Císarová, et al., 2016). Gupta & Saxena (2012) showed that essential oils from *O. kilimandscharicum* possess significant antifungal properties against *A. flavus*. Oregano and thyme essential oils inhibited 100% of the growth of all tested isolates of *A. flavus* studied (Foltinová, 2017). Testing in vitro several plant extracts on a strain of *A. flavus*, Yousef, et al., (2022) found that thyme extract was very effective, completely inhibiting the growth of this phytopathogen. Oregano oil showed in vitro antifungal activity against *A. flavus* and *Penicillium commune*, but this was lower than that of the volatile compounds identified in this oil and tested separately (Almeida, 2022). Mokhtari, N. et al. (2025) studied the chemical composition and antifungal effect of the oils of *Origanum compactum*, *Mentha pulegium*, *Lavandula officinalis*, and *Myrtus communis* on strains of *A. flavus* isolated from peanuts, noting that binary combinations of the oils exhibit greater antifungal activity than each oil alone, a finding also observed regarding the production of aflatoxin B1.

Botrytis cinerea and *Botrytis fabae* were inhibited by basil oil of the methyl chavicol chemotype, as well as by linalool chemotype oil (Oxenham et al. 2005; Stan et al. 2023). Xie, et al. (2022), studying the effect of several essential oils on the development of *B. cinerea* on post-harvest grapes, concluded that basil and thyme have an inhibitory effect on this pathogen, but at doses higher than 250 µL/L. Increasing the dose leads to a longer-lasting inhibitory effect. Nikolaos Tzortzakis, (2024) found that essential oil of *Origanum dictamnus* can reduce or delay lesions caused by *B. cinerea* on post-harvest pepper fruits when applied in vapor form. Other studies have shown that eugenol, which is a major compound in basil oil, has a stronger antifungal effect on *B. cinerea* than the tested oil that contains other compounds as well (Tudora et al., 2025). Almasaudi et al. (2022) investigated the antifungal activity of oregano oil against the mold *B. cinerea*, concluding that it, like cinnamon oil, could serve as an eco-friendly alternative to synthetic fungicides for controlling gray mold disease. Hou, H. (2020), while testing oregano essential oil and its major components (carvacrol and thymol), found that the oil exhibited moderate antifungal activity, whereas its main components showed greater antifungal potential against the phytopathogen *B. cinerea*. Akpo et al. (2023) found that the essential oil and aqueous extract of *Ocimum gratissimum* L. have an antifungal effect on the tested *B. cinerea* strain, while higher concentrations of essential oil were required for *Fusarium oxysporum*. The aqueous extract did not inhibit the *Fusarium oxysporum* strain at all, whereas *B. cinerea* was inhibited at concentrations of 60%. Zaharia et al. (2023) found that thyme oil is much more effective compared to oregano and basil oils in inhibiting pathogens such as *Fusarium spp*., *Penicillium spp*., and *Aspergillus spp*. Ruiz-Medina M. et al. (2024) demonstrated the efficacy of oregano and thyme oils against certain strains of *Penicillium spp*. and *Fusarium spp*., isolated from bananas, also noting that basil oil does not exhibit antifungal activity against the tested strains. Kocić-Tanackov et al. (2012) found that oregano oil has a stronger inhibitory effect on the growth of the tested *Penicillium spp*. strains compared to *Fusarium spp*. strains at the same applied concentrations. In vivo experiments against *Fusarium oxysporum* developed on potato tubers showed the efficacy, at low concentrations, of thyme and oregano oils, either alone or combined (Bounar, 2020). Other authors have noted the synergistic effect of the main compounds from several studied oils, including basil and oregano, on fungi responsible for the degradation of papaya fruits, including the *Fusarium* genus. Vitoratos et al. (2013) demonstrated that *P. italicum* showed no mycelial growth in the presence of thyme essential oils at relatively low concentrations. *B. cinerea* exhibited no mycelial growth in the presence of applied oregano essential oil. Additionally, both thyme and oregano oils inhibited spore germination for *P. italicum* and *B. cinerea.* In vivo experiments on tomatoes, strawberries, and cucumbers infected with *B. cinerea* demonstrated very high efficacy of oregano oil. García-Custodio, (2025) demonstrated that the oil of *O. vulgare subsp. virens* exhibits antifungal activity, inhibiting in vitro spore germination in *P. italicum* and *P. digitatum*. The same authors showed that the monoterpenes and phenolic esters present in essential oils have greater antifungal activity than the monoterpene alcohols, ketones, and ethers..

CONCLUSIONS

Basil, thyme, and oregano oils are rich in compounds with antifungal activity against certain species of Aspergillus, Botrytis, Fusarium, and Penicillium. According to data in the specialized literature, in vitro tests have demonstrated a higher efficacy of the major compounds compared to the oil itself. In addition to their antifungal activity, it has been found that essential oils of basil, thyme, and oregano can inhibit mycotoxin production as well as spore germination. In vivo, these oils have been tested less frequently, with more studies focusing on post-harvest production. More studies on the plants are needed to demonstrate the in vivo efficacy of essential oils or their compounds.

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