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REVIEW ARTICLE

Antibacterial and antifungal activity of essential oils

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ABSTRACT

The antimicrobial properties of essential oils are extremely significant. Essential oils are useful as an organic medicine for a variety of diseases also they are used in a variety of industries. From various research studies, this analysis shows some essential oils and their use against harmful bacteria. The researchers have devoted much focus to the study of natural antimicrobial compounds in medicine. This is mostly because of antimicrobial-resistant pathogens. Essential oils are volatile, natural, complex, strong odor compounds, which are formed as secondary metabolites by aromatic plants. They have been extensively used in applications including bactericidal, virucidal, fungicidal, antiparasitic, insecticidal, health, and antioxidants. The mechanism of action of essential oils makes them unique to be used against various pathogens. Many essential oils are study for their antifungal activities. Citronella, geranium, lemongrass, peppermint among others have been examined distinctively against fungi and found to be helpful antimicrobials for that purpose. In this review article, we will provide a summary of essential oils used against various pathogens, their mode of action, and future perspective for the use of essential oils as a potential antimicrobial.

Keywords: Essential oils, antibacterial activity, antifungal activity

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INTRODUCTION

Essential oils are derivatives of plants and have been of great importance for decades. As infectious organisms are emerging day by day, the lack of right and suitable treatment is increasing the global burden (Bhutta et al., 2014). Essential oils and their biological properties have proven a great replacement for chemical treatment and antibiotics (Chávez-González et al., 2016). Inhibitory properties against various human pathogens are attracting researchers to explore several kinds of plant extracts for their essential properties (Godstime et al., 2014).

The Essential oils also known as volatile oils are secondary metabolites synthesized by aromatic plants, which protect the plant against infectious lifeforms. They are highly complex chemical mixtures. The oils are primarily composed of sesquiterpenes and monoterpenes. They are generally fluid, colorful, and translucent, with a heavy odor (Sadgrove and Jones, 2015). Aromatherapy is one example of the use of essential oils by cancer patients to improve spirit, body, and mind (Ballard et al., 2002). Besides

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the property of aroma, many studies have been carried out to evaluate the activity of the essential property of volatile oils against the infectious family of microorganisms. Essential oils have been investigated extensively for their anti-inflammatory, anti-bacterial, anti-tumor, anti-fungal, antiviral, and antioxidant activities (Böhme et al., 2014; Ghosh et al., 2008; Kurita et al., 1981; Andrade et al., 2014; Sobral et al., 2014).

The use of essential oils as antimicrobials is a topic of the current study and a potential approach to the conservation of natural food. However, several genera represent the core for using essential oils against microorganisms, hence makes it difficult to test several essential oils (Rios and Recio, 2005). Several methods have been used to check the antimicrobial activity of essential oils against a diverse array of human pathogens, for example, screening of antimicrobial against pathogenic lifeforms has been extensively researched with disc diffusion method, microdilution assay, vapor phase method, direct contact method, and using ELISA microplates (Dobre et al., 2011; Dussault et al., 2014; Fabio et al., 2007). Kalaivani et al. (2012) have reported significant antimicrobial activity of *Coleus aromaticus, Ocimum sanctum,* and *Ocimum bacillicum* against species of bacillus, streptococcus, pseudomonas, klebsiella, shigella, and E.coli. The study and disc diffusion evaluation of EOs from fifteen plants have shown antifungal activity against *Aspergillus niger* and *Aspergillus fumigatus* (Bansod and Rai, 2008). Astani et.al have reported significant antiviral activity of natural mixtures from thyme, tea tree, and eucalyptus against Herpes simplex virus-1 utilizing the time of addition assay and dose-response assays (Astani et al., 2010).

The practice of medicine has been revolutionized by antibiotics in the clinical medicine spectrum, with more safety of the birth, surgical operations, organ transplantation, and the regimen of myeloablative chemotherapy. Antimicrobial resistance is increasing day by day with the use of drugs as the microorganisms are utilizing mechanisms to be resistant to the drug. The use of combinations of medications is one technique used to combat these resistance mechanisms. Most studies have been extensively researched on the synergy of essential oils with antibiotics to combat antibiotic resistance (Valdivieso-Ugarte et al., 2019). Many publications about the use of essential oils and antibiotics as combination therapy show remarkable promise, which means that the amount of antibiotics needed to fully kill multidrug-resistant infections has decreased considerably. Nevertheless, it raised a few problems in its implementation by using essential oils as components of combinatory therapy (El Atki et al., 2019; Langeveld et al., 2014; Moussaoui and Alaoui, 2016). One of the biggest difficulties is for example the solubility of the essentially hydrophobic oil in the aquatic medium. The proliferation of antibiotic-resistant bacteria from the overuse of antibiotics, along with the development of several synthetic chemical products designed to counter them, has prompted research into promising alternatives for drug-resistant microorganisms.

The interest in essential oils as a medicinal strategy to suppress antibiotic resistance is rising and the growing problem is that if these compounds are used clinically on a wide scale bacterial tolerance to essential oil components is inducted. The degree of tolerance to vital components of oil of bacteria is yet to be consistently and thoroughly assessed. Few experiments have been carried out while the emphasis has been on defining and enhancing the phytopharmaceutical library as a resistance modifier.

MECHANISM OF ACTION

Mechanism of action of essential oils against bacterial pathogens

The main mode of action showed that the essential oil worked on the cytoplasmic membrane, causing its integrity to be compromised and permeability to increase. Fundamental oils' lipophilicity makes them especially parcel from the watery stage to the nonpolar cell layer of microscopic organisms, bringing about film extension, expanded film ease and penetrability, interruption of layer inserted proteins, hindrance of breath, and changes in bacterial particle transport measures. To confirm the

oil's membrane disruption property, various assays were performed, including the LIVE/DEADTM BacLight Bacterial viability assay, the loss of 260 nm absorbing content, the release of cellular proteins, the detection of membrane disruption by SDS-PAGE, and SEM study (Khaled et al., 2021).

In specific cases, unadulterated fundamental oil compounds have higher antibacterial movement than the fundamental oil itself. Fundamental oil constituents like thymol, menthol, and linalyl acetic acid derivation have an antibacterial impact by disturbing the lipid parts of bacterial plasma films (Swamy et al., 2016). This can affect the membrane's permeability, resulting in intracellular material leakage.

One other method of activity of fundamental oils is - When bacterial cells were treated with the EO segments carvacrol and pcymene, they instigated the amalgamation of warmth stun proteins (HSPs). HSPs are atomic chaperones that assume a part in the gathering and arrival of recently blended polypeptides (Tariq et al., 2019). Their action ascends as microbes come into contact with hurtful substances or different stressors. At the point when E. coli O157:H7 cells were hatched for the time being within the sight of 1mM carvacrol, huge measures of warmth stun protein 60 (HSP60) (GroEL) were created, and flagellin blend was restrained, bringing about non-motile cells.

This has likewise been perceived that the pH of bacterial cells presented to EOs was estimated, and a considerable lessening was found. The activity of EOs on the layer, which loses its capacity to obstruct protons is accounted for and this can bargain pH homeostasis (Chimnoi et al., 2018).

In an examination, Intracytoplasmic changes were seen in E. coli cells treated with oregano EO, with coagulated substance showing up specifically territories close to the phone divider and apical finishes; at the point when E. coli cells were presented to cinnamon EO, the periplasmic space changed drastically, increasing and more irregular; the shortfall of fimbriae in the changed (bigger) periplasmic space was likewise noted by the scientists (Faleiro, 2011).

The inhibition of toxin secretion is another consequence of essential oils on cell membranes. It was discovered that exposing B. cereus to carvacrol prevented toxin development and that using oregano essential oil stopped S. aureus from developing enterotoxins. Because of the impact of fundamental oil compounds on the transmembrane transport component in the plasma layer, the emission of poisons can be forestalled by changes in the bacterial film, restricting the arrival of poisons to the outer climate (Swamy et al., 2016).

Anti-quorum sensing activity of essential oil also plays an important role in the mechanism of action of EO. Various mechanisms have been suggested to understand how essential oils interact with quorum sensing-dependent processes. Inhibition of signal molecule biosynthesis or AHL signal receipt, as well as enzymatic inactivation and biodegradation of quorum sensing molecules, are examples of these mechanisms.

Mechanism of action of essential oils against fungal pathogens

Essential oils have antifungal properties that are close to those of previously described antibacterial mechanisms. Some other modes of actions are- If ergosterol is bound by antifungal agents of essential oils or their biosynthesis is blocked by particular inhibitors, the integrity and function of the fungal cell membrane would be disrupted (Swamy et al., 2016).

Through a permeabilization component, fundamental oils can infiltrate and upset the contagious cell divider and cellular material layers, bringing about the breaking down of mitochondrial films. Essential oils can inhibit the activity of the Mitochondrial electron transport chain, resulting in a reduction in mitochondrial membrane potential. The inhibition can also occur through the inhibition of proton pumps in the respiratory chain, resulting in a decrease in ATP output and cell death. Essential oils can also help in reducing drug resistance- Overexpression of these efflux forms may contribute to drug resistance, but their invention can minimize drug resistance. Efflux pumps are found in all living cells and extract harmful compounds from the cell. They also transfer stored drugs out of the fungal cell.

Antibacterial activity of essential oil

Essential oils' antibacterial activity is determined by their chemical structure and the amount of each compound present. The antibacterial activities of oils are generally determined by the composition, structure, and functional groups of the oils (Soetjipto, 2018). Essential oils were found to have antibacterial effects against a variety of bacteria, including *Listeria monocytogenes*, *Listeria innocua*, *Salmonella typhimurium*, *Escherichia coli*, *Shigella dysenteria*, *Bacillus cereus*, *Staphylococcus aureus*, and *S. typhimurium*, also some studies showed that antibacterial activity has been found in certain essential oils against zoonotic enteropathogens such as *Salmonella spp.*, *E. coli O157*, *Campylobacter jejunii*, and *Clostridium perfringens* as well as, essential oil variants of oregano and thyme, oregano and marjoram, and thyme and sage demonstrated intense antibacterial effects against *B. cereus*, *Pseudomonas aeruginosa*, *E. coli O157:H7*, and *Listeria monocytogenes* (Shaaban et al., 2012).

Usually, essential oils have a stronger impact on Gram-positive bacteria than on Gram-negative bacteria, and the lack of antibacterial activity against Gram-negative bacteria has been attributed to the presence of an outer membrane with hydrophilic polysaccharide chains that acts as a barrier to hydrophobic essential oils (Inouye et al., 2001). It has been found that *Micrococcus yunnanensis* has the highest sensitivity to rosemary, eucalyptus, lemon grass, clove, and cinnamon among all Gram-positive bacteria, while *E. coli* has the highest sensitivity against those five essential oils among gram negative bacteria.

To improve bacterial resistance to antibiotics scientists are currently researching the potential of the plant extract as antimicrobial resistance to antibiotics is rising rapidly. When antibiotics and essential oils are combined, three major forms of interactions occurred and those are synergism, additivity, and antagonism; among them, if the combined effect of the chemicals are greater than the effect of a single chemical will referred to as a synergistic interaction; if the number of two chemicals equals the sum of chemical effects alone will called additive interaction, and if the combined effect of two chemicals are less than the amount of the effects of a single chemical alone will identify as antagonism (Aljaafari et al., 2019). Over 1340 plants have antimicrobial compounds that have been identified, and more than 30,000 elements have been isolated from phenol group-containing plant-oil compounds and used in the food industry (Shaaban, 2020). Use of spices and their essential oils for food preservative as natural agents have currently been focused on expanding the shelf life of foods, decreasing, or removing pathogenic bacteria, and improving overall food safety (Burt, 2004; Razzaghi-Abyaneh et al., 2009; Shaaban, 2020).

Various mechanisms have been discovered to be responsible for the essential oil's antibacterial action in the vapor process, including cell wall breakdown, cell membrane disruption, membrane protein structural changes, cytolymph leakage, cytoplasm condensation, and changes in nuclear activity (Wu et al., 2019). Organic molecules have been associated with a variety of diseases, including cancer, degradation of food organoleptic and hygienic consistency, and neurodegenerative diseases; furthermore, antibiotic resistance has escalated massively because of extensive use of antibiotics, which is another public health

problem (Chouhan et al., 2017). Many studies have analysed the ingredients and antibacterial functions of essential oils which have extensive uses in the fields of food preservation, agricultural products preservation, air disinfection, and mildew proofing.

Clove essential oil have a high concentration of eugenol, which is responsible for its biological and antimicrobial properties (Nuñez and D'Aquino, 2012). The antimicrobial and antibacterial activities of Geranium essential oil make it useful against several bacterial strains and it was found that this essential oil is almost as effective as amoxicillin to inhibit bacterial strains, such as *Staphylococcus aureus* (Ghannadi et al., 2012; Whelan, 2019). Terpinen-4-ol is one of the most essential compounds found in tea tree oil that have been exposed to fight against specific bacteria, viruses, fungi; also white blood cells become more active when exposed to terpinen-4-ol which aids in the fight against germs and other foreign invaders and due to the germ-fighting capabilities tea tree oil is known as beneficial natural remedy for treating bacterial and fungal skin problems, averting infection, and promoting wound healing (Budhiraja et al., 1999; Carson et al., 2002; Li et al., 2016). One of the vital compounds in thyme essential oil is thymol that is traditionally used as an expectorant, antiviral, antibacterial, and antiseptic substances in conventional medicine; especially for the treatment of upper respiratory tract (Kowalczyk et al., 2020). Oregano contains antioxidant compounds known as phenols, terpenes, and terpenoids, that are responsible for its fragrance and carvacrol is the most significant phenol in oregano also the growth of several forms of bacteria has been shown to be inhibited (Rowles, 2020). One study showed that, oregano was the second most effective essential oil against bacteria, after thyme (Fournomiti et al., 2015; Link, 2017). List of several essential oils and their usages have been mentioned in **Table 1**.

Table 1: List of several essential oils and their usages

Essential oils	Scientific Name	Usages	Source
Clove	*Syzygium aromaticum*	i. *Staphylococcus aureus* is the most common cause of bone infections. Cloves have antibacterial properties against Staphylococcus aureus that helps in formation of strong bones. ii. Bacterial meningitis can cause stroke, hearing loss, and permanent brain damage; mainly, *Pneumococcal meningitis* is the most common form of meningitis. Various studies showed that cloves contain manganese and have antibacterial properties against *Pneumococcal meningitis* that helps in maintaining the brain function. iii. Clove oil help to prevent bacteria that cause gum disease and food poisoning, as it has antibacterial properties against Gram-negative bacteria like *Pseudomonas aeruginosa*, Salmonella, and Gram-positive bacteria that are commonly present in food, including Streptococcus and Staphylococcus.	(Cai and Wu, 1996; Liu et al., 2014; Macon, 2018; Nuñez and D'Aquino, 2012; Nzeako et al., 2006; Palacios, 2006; Pham-Huy et al., 2008; Shaaban, 2020; Takeda, 2003)

Geranium	*Pelargonium*	i. ii.	Some bacteria cause wound and swelling. The anti-inflammatory properties of geranium essential oil can make it useful for edema-related leg and foot swelling. According to few reports, there might be a correlation between bacteria in various parts of the body and type 2 diabetes. Research show that geranium essential oil could help people with diabetes to control their blood sugar levels, although more analysis is needed.	(Boukhatem et al., 2013; Huzar, n.d.; Whelan, 2019)
Tea Tree	*Melaleuca alternifolia*	i.	Tea tree oil is an effective organic hand sanitizer as it kills many common bacteria and viruses that cause diseases, such as E. coli, S. pneumoniae, and H. influenzae. A mild to strong odor is formed when secretions from sweat glands interact with bacteria on the skin. Tea tree oil is a natural alternative to commercial deodorants and antiperspirants for its antibacterial properties, that help in the control of perspiration-related underarm odor.	(Carson et al., 2006)
Thyme	*Thymus vulgaris*	i. ii.	Thyme and thymol have antibacterial properties against bacteria such as *salmonella*, *Staphylococcus aureus*, and *Helicobacter pylori*, which have been shown to be useful in the treatment of food-borne bacteria that helps in food preservation. Thymol is useful to oral health because of its anti-inflammatory and antibacterial effects. Several dental products contain thymol including “Listerine cool mint” mouthwash.	(Borugă et al., 2014; Patole et al., 2019; Whelan, 2019)
Oregano	*Origanum vulgare*	i.	*Escherichia coli* and *Pseudomonas aeruginosa* are two bacteria strains that can cause urinary and respiratory tract infection, which can inhibit by oregano essential oil.	(Man et al., 2019; Rowles, 2020; Sienkiewicz et al., 2012)

		ii.	Oregano is indeed a natural antibiotic that prevents food poisoning and skin infections caused by *Staphylococcus aureus*.

Antifungal activity of essential oil

Essential oils are extracted and distilled oils of various plants. These oils contain the chemical compounds that characterize and support the life cycle of the plant. Many essential oils are natural substances with powerful properties. Many essential oils are antifungal or antimicrobial, meaning they are going to fight the expansion of certain pathogens that may harm your health. Since volatile oil does not trigger the same side effects as some synthetic ingredients that are used to fight bacteria and fungus, they are becoming more and more popular to be used for that purpose. Fungi are leading to health conditions like ringworm. Essential oil represents novel alternatives to the application of synthetic fungicides to regulate against seedborne pathogens. This study investigated seven essential oils for in vitro growth inhibition of the most seedborne pathogen. The essential oils of herbs and spices are a spread of the foremost powerful antimicrobial essential oils. Thyme, cinnamon, oregano, clove, and mint are all samples of these kinds of oils. Citronella, geranium, lemongrass, eucalyptus, and peppermint, among others, are tested precisely against fungi and found to be helpful antimicrobials for that purpose. Tea tree oil is another essential oil that must exemplify antifungal essential oils. Essential oils have antiseptic, antiflammatory and fungicidal properties. Some can even restore new cell growth. These properties work together to make a potent treatment for fungal infections on your skin.

Many researchers have demonstrated that essential oils, due to their effectiveness, low toxicity, and low persistence within the environment should be used as a promising short alternative to synthetic fungicides. Anti-fungal medication is out there over the counter, but these medications can often cause nasty side effects. Essential oils are often used safely to treat fungal infections within the knowledge that you are highly unlikely to develop any side effects which your body will not build in need of immunity against them. Many essential oils are analysed for their antifungal activities.

Phytopathogenic fungi are a significant threat to plant health and causing a plethora of diseases that put up substantially to overall losses the agricultural field. Additionally, fungal plant pathogens are divided into two main groups, which form intimate interactions with plants and continue and utilize living tissues that kill the nutrient to extract nutrients. Fungi are very difficult to focus on due to cellular and diatomic expressions, human pathogenic fungi, and eukaryotes that are very related to their host. Although, eukaryotes and human pathogenic fungi and their hosts have comparisons at molecular and cellular levels. Human mycosis pathogens like *Aspergillus spp., Cryptococcus spp*., and *Candida spp*., are very troublesome for immunosuppressed patients. Hence, a restricted number of antifungal drugs are accessible against fungi. Presently, recommended drugs are resistant to fungal strains, and many give rises to cause biofilm infections and adverse reaction. Plant essential oil that are efficacious against human pathogenic mycosis, herb mycosis, and yeast mentioned in **Table 2**.

Table 2: Essential oil as antifungal agents

Essential oil sources	Fungi	Source
Rosmarinus officinalis (rosmery)	*Alternaria alternata*	(Boukhatem et al., 2013)
Matricaria chamomilla (chamomile)	*Aspergillus niger*	(Tolouee et al., 2010)
Piper nigrum (black pepper)	*Candida albicans*	(Zhang et al., 2021)
Artemisia Judaica (wormwood)	*Cladosporium*	(Kurita et al., 1981)
Lavandula sp; *Ziziphora clinopodioides*	*Cryptococcus neoformans*	(Kordali et al., 2005)
Carum nigrum (black caraway)	*Penicillium sp.*	(Fathifar et al., 2021)

Plant-like oregano, thyme, garlic, bay leaf, rosmery, and clove or their extracts indicate as essential oils are often used alone or combined with other preservation methods, like irradiation or modified atmosphere packaging (MAP), to enhance the time period of food products (Tullio et al., 2007). Essential oil is too complex and lots of essential oils contain 20-60 individual volatile compounds. The main components are hydrocarbons (pinene, limonene, bisabolene), alcohols (linalool and sotalol), acids (benzoic acid and geranic acid), phenols (anethole), esters (geranyl acetate). Due to board range of antimicrobial and other beneficial effects, essential oil-producing plants have been used as medicinal plants over thousands of years. In total 25000 essential oil are known, of which approximately 300 are commercially important. In medicine, only a few essential oils utilized in aromatherapies.

Pathogenic fungi are the main infectious agents in plants causing huge losses in yield and quality of field crops, fruit, and edible plant materials. These agents could also cause serious effects on human health. Essential oils are often extracted from several plants with different parts extraction methods. The synthesis of essential oil and therefore the method used for essential oil extraction are normally hooked into botanical material used. Extraction method is one of the prime factors that determines the standard of essential oils. Improper extraction procedures can lead to the damage or alter the action of the chemical signature of essential oils (Kalemba and Kunicka, 2003). Interest within the antifungal activity of essential oils has increased markedly in recent years. The volatile component of several essential oils has been exemplified to possess potent antifungal activity. Although the antifungal activity of essential oil volatiles was first reported in 1959, specific antifungal activity related to these volatiles has, until recently, focused on inhibition of either food spoilage or plant pathogens, with little known about their potential activity against medically important fungi.

CONCLUSION

Essential oil's antibacterial function has a significant positive effect in the pharmaceutical industry, food processing, agriculture, herbal cosmetics, and other fields. Many studies have shown that essential oils are effective against toxic bacteria. To save and maintain the ecological balance, natural products should be appraised as a possible option. For example, the use of essential oils as antibacterial properties needs to be more as organic products rather than toxic substances. Interest within the antifungal essential oils has increased markedly in recent years. Antifungal essential oil work to form a potent treatment for fungal infection which frequently act on your individual body parts. Due to wide-ranging of antimicrobial and other helpful effects, antifungal essential oil-producing plants have been used as medicinal plants over thousands of years.

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