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Review Article

A Leading Role of Essential Oils Against Biofilm Forming Bacteria

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Abstract

Antimicrobial resistance is an growing worldwide threat to human as well as animal health. where different microorganisms like bacteria, viruses, fungi, and parasites change to become unaffected to drugs intended to kill or inhibit them and acquiring new ways to skip the effect of these drugs. biofilm formation in some bacteria has earned a special attention. It not only protects bacteria from external foes but also prevent the entry of drug inside the organism providing good option to remain unaffected for long period of time. Among the various other agents now used as an alternative to various antibiotics Essential oils (EOs) have added special attention as potential agents to fight against the antimicrobial resistance (AMR) and biofilm-associated infections, due to their broad-spectrum activity and complex chemical composition.

Keywords: Antimicrobial Resistance (AMR); Essential Oils (EOs); Bacteria

Introduction

In order to endure antibiotic resistance, bacteria are continuously developing new guard mechanisms, also known as resistance mechanisms. For instance, production of enzymes called ESBLs, which degrade and break down some of the most widely used antibiotics, such as penicillin, cephalosporin, and other antibiotics, rendering these drugs ineffective in treating infections. In addition, if such resistant microorganisms form biofilm renders them more resistant towards complex treatment [1]. Even though the story of resistance started long back with the discovery of penicillin the methods adopted by these microorganisms with the passage of time has made the things scarier as it may lead to multiple drug resistance through cross resistance. Antibiotic treatment of biofilm infections is often ineffective, making them hard to exterminate. Adding to these constraints, the presence of biofilm in infections for a longer time further makes it difficult to eradicate with antibiotics, and thus could be a possible reason for problems in the normal treatments.

Biofilm and its role in AMR

Biofilm can be named as a coherent group of bacterial cells placed inertly in a biopolymer environment. In comparison to the planktonic cells, they show resistance towards the host defence and tolerance against the antimicrobial properties of the antibiotics used [2]. Some of the researchers predicted them as a default means of growth of bacteria without knowing the function of the matrix formed [3,4]. However, it seems that the formation of a biofilm, and incasement of cells in a polymer-based matrix, decreases the predisposition to antimicrobials and immune defenses, making these infections difficult to eradicate. During contamination, spreading of cells from the biofilm can result in spread to secondary sites and worsening of the infection. As the biofilm matures, proteins, DNA, polysaccharides, etc. are concealed into the biofilm by the deceived bacteria. After biofilm maturation the dispersal step follows, which is also critical for the biofilm life cycle, Dispersal could occur in the whole biofilm or just a part of it. Release of planktonic bacteria promotes the initiation of new biofilms at other sites.

Few researches mention that antibiotic treatment of biofilm infections is often unsuccessful due to less penetrability, per sister cell formation, nutrient deficiency, phenotypic variation and thus the infections are difficult to eradicate [5,6].

The hazard multiplies significantly if these biofilms are found in resistant isolates such as extended spectrum beta lactamase or methicillin-resistant Staphylococcus aureus (MRSA). Immersion in biofilms increases the resistance of microorganisms to biocides. Recently, a greater focus has been on finding natural alternatives that help prevent and control biofilms. Recently, most essential oils have gained a new role in combating these organisms that produce biofilms.

Role of essential oils

Essential oils are among the few compounds produced by plants' secondary metabolism. They are described as intricate blends of volatile substances prevalent in the leaves, flowers, stem, roots, seeds, and fruits of aromatic plants. In recent years, they have been introduced as food additives, preservatives, and medicaments like antiseptics, anti-inflammatory, and analgesics. Some of the EOs and their components have demonstrated relevant antimicrobial potential against a wide range of microbial pathogens. The wide-ranging effectiveness of essential oils is due to the presence of aldehydes, phenolic compounds, and terpenes produced through secondary metabolism in different parts of plants and the capacity of their components to interact with cell membranes, which disrupts microbial integrity and results in cell death. Nevertheless, the bioactive constituents of EOs can target multiple cellular sites, primarily associated with cytoplasmic coagulation, inhibition of enzymes responsible for ATP production, changes in ion transport, damage to the cell wall, and destruction of bacterial membranes, the most commonly used oils include lemon, peppermint, citronella, eucalyptus, mint, and orange. For domestic use, tea tree, peppermint, Chamomile, lavender, rosemary, orange, lemon, rose, eucalyptus, jasmine, geranium, sandalwood, and frankincense oils are the most popular. Although the number of effective essential oil-based antibiofilm agents is increasing, developing antibiofilm medications remains a significant challenge. The EO compounds identified so far with this activity require additional optimization to enhance their effectiveness before they can be considered as clinical candidates for this purpose. It is also essential to take into account other characteristics of EOs, such as their stability, volatility, encapsulation, and ideal dosage in the creation of EO-based antibiofilm medications. Nevertheless, it is anticipated that some of these compounds will be successfully developed into antibiofilm drugs in the near future.

Cinnamon oil comprises compounds like cinnamaldehyde, which prevents bacterial biofilm, suppresses bacterial attachment, colonization, and the early stage of biofilm formation. One of the main *Cinnamomum* ingredients, containing about 65% of it due to its acrolein group (α, β-unsaturated carbonyl moiety), could be associated with the antimicrobial activity of *Cinnamomum.* Cinnamon oil is a more potent antimicrobial agent than cinnamon extract, and it has the potential to be used as a food bio preservative. Biofilms are responsible for most of the interference caused by microorganisms in food processing.

Essential oils extracted from green leaves of Eucalyptus sp. to evaluate *in vitro* antimicrobial and antibiofilm activities against 26 bacterial strains including 11 reference strains and 15 antibiotic resistant and multi-resistant *E. faecalis* strains using the disc diffusion method with lowest MIC (3.12 to 6.25%), when compared with reference *E. faecalis* strain, but little or none ability to inhibit the preformed biofilm [7].

The bactericidal effects of ginger oil (GO), peppermint oil (PO), curcumin (CU), cinnamon aldehyde (CI), and trans-cinnamaldehyde (TCI) on the adhesion and biofilm disruption of three references and five clinical *C. difficile* strains of different biotypes using the broth microdilution method. The adhesion was evaluated using human epithelial cell lines, and biofilm formation was visualized by confocal laser scanning microscopy [8].

Garlic oil contains organosulfur compounds such as allicin, ajoene, and allyl sulfides, which are responsible for its antibacterial and antibiofilm properties [9]. Garlic essential oil (G essential oil) showed more potential to inhibit *S. typhimurium* biofilm at different sub-minimum inhibitory concentrations as compared to thyme essential oil (T essential oil) [10,11].

Study observed on some other essential oil like peppermint, lemon balm and coriander seed oils revealed peppermint and coriander seed oils being even more potent than the antibiotic rifaximin in the disc diffusion assay and as antibiofilm agent [12,13], cell attachment of *Escherichia coli and Staphylococcus aureus* was strongly impaired by coriander, anise and peppermint essential oil and extracts. Coriander essential oil showed the highest antibiofilm activity against biofilm formed by both tested bacteria and observed antibacterial activity of mint and other plant extract against *E coli* and highest zone of inhibition was reported by mint extracts [14].

Azadirachta indica, *Moringa oleifera*, *Murraya koenigii*, and *Psidium guajava* extracts were investigated against MRSA. The preliminary antimicrobial study showed ether extract of *A. indica* and ethanolic extract of *P. guajava* showed a MIC value of 125 mg/mL and MBC value of 500 mg/mL. These extracts showed biofilm inhibition in the range of 60.0–83.9% [15]. Herbs are frequently used as a natural remedy to cure various ailments; plants rich in alkaloids, flavonoids, tannins, and polyphenols have been used to cure ailments because of their pharmacological properties [16]. Another study by reported 500 µL/L of Mint essential oil with the highest inhibition of bacterial growth also the antimicrobial effect of peppermint oil in meat products [17,18].

Eugenol is the main component of clove oil which imparts antibacterial, antioxidant, and anti-inflammatory properties to clove oil, purified clove oil after extraction from the clove buds, not only inhibited resistant *Helicobacter pylori* but also produced anti-inflammatory effect. Investigation also revealed its remarkable effect on the biofilm formed by *Helicobacter pylori* gut bacteria [19].

Other reports revealed that clove oil gave highest per cent inhibition against ESBL enzyme obtained from resistant *E. coli* isolated from healthy poultry. *Punica granatum* portrayed lesser per cent inhibition with both the indicators like CENTA and NITROCEFIN. There was increased per cent inhibition when both the herbs were combined together, standard control included drug Tazobactum, (100 µM), screened extracts of cloves and cinnamon for their antibacterial activity against the pathogenic organisms in the chicken meat. Essential oil from cloves showed slightly higher activity than cinnamon oil [20].

Conclusion

In recent research, lots of emphasis has been given to the plant extracts and their use as antimicrobial agents against different pathogens. Apart from plant extracts, various essential oils obtained from different herbs has also given its potential role in the antimicrobial effects, and with various findings their use against multidrug-resistant microorganisms and as antibiofilm agents are also put on record in recent years. The present review has included most of the information regarding various investigations on essential oils, their ability to inhibit the formation of biofilm, and control antimicrobial resistance. Some of the oils have also been reported as strong biofilm inhibitors; low concentrations of these oils showed an effect against most of the gram-positive as well as gram-negative bacteria.

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