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The Antibacterial Effect of Plant-Based Essential Oils

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Abstract: *One of the advantages of using esential oils as an alternative therapeutic is that it has a wide range of antimicrobial activity. Essential oils of plants are composed of a mixture of aldehydes, alcohols, terpenoids and other compounds. Also currently the plant products have found wide application as alternatives to conventional therapy and food preservation. The essential oils are substances obtained from plant materials as flowers, leaves, fruits, branches, seeds, bark by different methods. The essential oils are secondary metabolites produced by plants in order to provide a defense function or attraction. Its range of action extends to both Gram negative as Gram positive bacteria and the antibacterial mechanisms are varied.*

Keywords: *Essential oil, antibacterial, plant, Gram negative, Gram positive.*

1. Introduction

The medicinal plants have been used for therapeutic purposes since ancient times. The use of plants as traditional medicine in the treatment of various diseases dates from long before the discovery of the existence of microorganisms (Ali *et al*., 2015; Gutierrez *et al*., 2008; Patra and Baek, 2016). There are countless plant chemicals that can be considered drugs and are used in one or more countries, of which 74% were discovered from use in traditional medicine (Ahmad, 1998; Ali *et al*., 2015). One of the advantages of using plants as an alternative therapeutic is that it has a wide range of antimicrobial activity because it contains a lot of active ingredients that make it toxic to microorganisms. Essential oils of plants are composed of a mixture of aldehydes, alcohols, terpenoids and other compounds (Diao *et al*., 2013). Currently the plant products have found wide application as alternatives to conventional therapy and food preservation (Carhuapoma *et al*., 2009; Castaño *et al*., 2010; Patra and Baek, 2016; Rincón-Mejía *et al*., 2012). Generally, essential oils of plants have been widely used for the treatment of various diseases which is why many medicinal plants have attracted scientific interest; they have antioxidant and anti-inflammatory properties (Patra and Baek, 2016; Sacchetti *et al*., 2005; Sokmen *et al*., 2004; Wu *et al.*, 2009). Also it has been associated with modulation of various genetic pathways (Khoury *et al.*, 2016).

In recent years there has been increasing interest in the use of biologically active organic compounds which are extracted from plant species that have the ability to eliminate pathogenic microorganisms by themselves; this is mainly due to the resistance that microorganisms have developed to antibiotics (Daferera *et al*., 2003; Marston *et al.*, 2016).

2. The Essential Oils as an Antimicrobial Alternative

The aromatic essential oils are substances obtained from plant materials as flowers, leaves, fruits, branches, seeds, bark by different methods (Burt, 2004; Castañeda *et al*., 2007; Citarasu, 2010; Cowan, 1999; Sánchez *et al*., 2009). The essential oils are secondary metabolites produced by plants in order to provide a defense function or attraction (Butkiené *et al*., 2015). The defense mechanisms related to secondary metabolites include flavonoids, phenols, terpenes, oils, alkaloids, lectins and polypeptides (Solórzano-Santos and Miranda-Novales, 2012). Previously essential oils were used as flavorings or for cosmetic purposes (Ali *et al.*, 2015). However, in recent years the discovery of its chemical components has aroused great interest because researchers have characterized some of them as potent antimicrobials and antioxidants (Burt, 2004; Sacchetti *et al*., 2005). In addition to the above, essential oils are characterized by a complex mixture of several compounds belonging to different classes of organic chemistry, for example: hydrocarbons, phenols, terpenes, alcohols, aldehydes, ketones, esters, ethers and others (Butkiené *et al*., 2015; Castañeda *et al*., 2007; Hassan *et al.*, 2016; Kordali *et al*., 2005).

The essential oils have demonstrated insecticidal properties, antioxidant, antibacterial, antifungal and antiviral (Cowan, 1999; Gracia-Valenzuela *et al.*, 2012; Kim and Park, 2013; Kordali *et al.*, 2005; Sacchetti *et al*., 2005; Wojnicz *et al*., 2012). It has been shown that *Lippia berlandieri* (oregano), *Thymus vulgaris* (thyme) and *Cinnamomum verum* (cinnamon) have antioxidant properties related with phenolic compounds such as carvacrol and thymol and these can be used under certain conditions as fungicides and bactericides (Abdalá and Roozen, 2001; Burt, 2004; Cowan, 1999; Kordali *et al*., 2005). Some phenolic compounds derived from plant extracts have been reported as viable alternatives to antibiotics for the treatment of infectious agents in aquaculture (Citarasu, 2010).

3. THE ANTIBACTERIAL ACTIVITY SPECTRUM

It has been reported by several authors that aqueous and alcoholic extracts of leaves, stems and roots from *Rhizophora mangle* (red mangrove) have inhibitory effect on growth of *Streptococcus pnemoniae, Staphylococcus aureus, Salmonella typhi, Escherichia. coli, Corynebacterium diphtheriae*, *Pseudomonas aeruginosa and Mycoplasma pneumoniae* (Ferreira *et al*., 2011). Erkana *et al*., (2012) demonstrated the antibacterial activity versus Gram-negative bacteria of a group of terpenoids extracted from leaves of *Murraya koenigii* (curry). Prabuseenivasan *et al*., (2006) reported that 19 essential oils showed antibacterial activity. They demostrated a significant inhibitory effect by cinnamon, clove, geranium, lemon, lime, orange and rosemary oils. Cinnamon oil showed the highest activity at low concentrations; aniseed, eucalyptus and camphor oils showed the lowest antibacterial activity against the tested bacteria both Gram-negative and Gram-positive: *Klebsiella pneumoniae, Proteus vulgaris, Bacillus subtilis, E. coli, P. aeruginosa, and S. aureus*. It has been reported also the potent inhibitory effect of essential oil of oregano, thyme and basil on the growth of *E. coli* and *P. aeruginosa* (Al-Bayati, 2008; Gracia-Valenzuela *et al*., 2012; Paredes-Aguilar *et al.*, 2007). Fig. 1 shows the inhibitory effect on growth of *E. coli* using the essential oil of thyme. It is a clear proof of the bactericidal effect of essential oils. Gualtieri *et al.*, (2008) evaluated the antimicrobial activity of the ethanolic extracts of leaves from *Azadirachta indica* (neem) on Gram-positive and Gram-negative bacteria, having a greater antimicrobial activity against Gram-positive bacteria.

Fig1. *The inhibitory effect of essential oil of thyme on E. coli growth. Diffusion test on agar with different concentrations of oil*

On the other hand, it have been studied the antibiofilm activity in bacteria from plant products or extracts that are rich in bioactive compounds (Chmit *et al*., 2014). Naturally, bacteria are forming biofilms which are complex communities surrounded by a exopolymer matrix. Bacteria form colonies adherent to inert surfaces or human tissues and organs (Ceri *et al.*, 1999; Donlan, 2011; Flores-

Encarnación *et al*., 2014). It has reported that a biofilm consist of bacteria, water, exopolisacaride matrix, proteins, nucleic acids and bacterial lysis products (Decho, 2013). It has been reported that about 70% of human bacterial infections involve biofilms (Bjarnsholt, 2013; Potera, 1999). Biofilms have become the leading cause of infections related with medical devices, for example: vascular catheters, prosthetic joints and others (Donlan, 2011; Flores-Encarnación *et al*., 2014). Bacteria in biofilms can be up to 1 000-fold more resistant to antibiotic treatment than the same planktonic bacteria (Bjarnsholt, 2013; Flores-Encarnación *et al*., 2009).Wojnicz *et al*., (2012) showed that *Betula pendula* (birch) affected the expression of virulence factors and biofilm formation by uropathogenic *E. coli*. It inhibited between 43-80% biofilm formation by *E. coli*, while Kim and Park (2013) showed that toluene extract from *Zingiber officinalis* (ginger) inhibited between 39 -56 % biofilm formation by *P. aeruginosa* PA14.

In all cases it has been observed that growth inhibition depends on the bacterial genus and concentration of essential oil probed. Por example: it has been reported that growth of *Staphylococcus epidermidis* and *S. aureus* (using the oil extracted from leaves and flowers from *Acmella ciliata*, misnamed weeds), it is inhibited by concentrations at 15-25 mg/mL. Instead the oil from *Lippia berlandieri* (oregano) inhibited growth of *Pseudomonas fluorescens*, *P. putida*, *Vibrio mimicus*, *V. alginolyticus* at low concentrations of oil (50 -100 μg/mL) (Gracia *et al*., 2012; Rincón *et al.*, 2012). Something similar happens to growth of *Helicobacter pylori* which is inhibited by concentrations at 2 μg/mL using the oil extracted from *Minthostachys mollis* (muña) (Carhuapoma *et al.*, 2009).

4. The Mode of Action of Essential Oils

The essential oils have been used in various applications, for example: stimulating agents, diuretics and anti-rheumatic agents, some possessing insecticidal, antifungal and antibacterial activities against pathogenic microorganisms (Chmit *et al*., 2014). Because its effectiveness against a considerable number of pests, their low mammalian toxicity and general availability, they have been considered as active ingredients in some botanical pesticides (Mohan *et al*., 2011). Although the biological activity of essential oils has been confirmed by numerous studies, there has been a great variability among them; this it has been attributed to the composition of the oils. The different factors what influence in composition of essential oils have been reported, for example: physiological variations, environmental conditions, oil origin and method of production, storage conditions, climate of the geographical region, season year´s, genetic factors and evolution. Also it has been reported that the maturity of the plant at the time of essential oil producing plays an important role in its composition (Figueiredo *et al*., 2008).

On the other hand, some mechanisms from antibacterial activity of essential oils have been determined. It has been reported that the antimicrobial activity depends mainly of chemical composition (hydrophilic or hydrophobic) of essential oil and microorganism that attack (Holley y Patel, 2005; Fisher y Phillips, 2008; Solórzano-Santos y Miranda-Novales, 2012). The hydrophilicity or hydrophobicity of the essential oil could be indicated whether it has the ability to alter and to penetrate the lipid membrane of bacteria, making it more permeable and causing leaking ions and cytoplasm and thus the lysis and death of bacteria (O'Bryan *et al*., 2015). In the cases mentioned above it has been observed the destabilization of bacterial cell membrane and wall, changes in bacterial membrane structure, alteration of the cell permeability, disturbance on respiration, modification of bacterial quorum sensing, potassium leakage from cells, effects on membrane potential (proton translocation), changes in pH gradient and ATP production of bacterial cell (O'Bryan *et al*., 2015). The terpene compounds are involved in the destabilization of the bacterial membrane (Rajendran *et al.*, 2014). It has been postulated that the alkaloid compounds intercalate into double-stranded DNA, while lectins and polypeptides can form ion channels in the bacterial membrane or cause competitive exclusion by adhesion of bacterial proteins to host polysaccharides receptors (Cowan, 1999). Another reports indicate that the components of essential oils interfere with the functions of cell membrane permeability (Lambert *et al*., 2001). Jasmine *et al*., (2011) described the possible modes of action for terpenoids: 1). It increases membrane permeability to small ions; 2). It affects the structural stability of the membrane; 3). It destabilizes the packing of the lipid bilayer.

It has been described that some of the essential oils are more active against Gram-positive bacteria but other are more active against Gram-negative bacteria (Tiwari *et al.*, 2015). Other authors have reported that Gram negative bacteria are more resistant to essential oils than Gram positive bacteria (Trombetta *et al*., 2005). As it is known Gram negative bacteria have an envelope consisting of lipopolysaccharides linked to outer membrane which restrict diffusion of hydrophobic molecules (Nazzaro *et al*., 2013). So Gram negative bacteria require greater concentrations of essential oils to inhibit their growth (Trombetta *et al*., 2005). Also it has been reported that the essential oils are equally effective in both bacteria. The difference is that to achieve the same lethal effect in Gram negative bacteria when bacteria are exposed more time to essential oil (Fisher y Phillips, 2008; Tajkarimi *et al*., 2010).

Considering the wide variety of chemical compounds that are part of the essential oils, the researchers propose that the antimicrobial activity is a synergism between the major components of the oil, so it could be more than one mechanism of action involved.

5. CONCLUSION

The antibacterial resistance is a serious problem distributed around the world that has been impacted on public health. For that reason it has revived the interest in essential oils and bioactive compounds as a possible alternative for the treatment and control of pathogenic bacteria and infectious diseases that cause them. In addition to the health area, essential oils are used in the food industry and agriculture as valuable biological pesticides, thanks to their antimicrobial properties.

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