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RESEARCH ARTICLE

THE BIOPESTICIDE ACTIVITY OF ESSENTIAL OILS

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ABSTRACT

In the field, pests are undesirable due to the economic losses they cause. The use of synthetic pesticides has long been the measure to combat many pests, however their use has generated pollution problems for the environment and, therefore, for human health. For this reason, other alternatives that are more environmentally friendly and that are less toxic to animals and humans are being investigated. Thus, the extracts of some plants and their components, such as essential oils, seem to be a possible source to treat various pests in agricultural and urban areas, through biopesticides.

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INTRODUCTION

Pesticides are compounds that are used to control a variety of pests. The positive aspect of application of pesticides renders enhanced crop productivity and drastic reduction of vector-borne diseases (Yadav *et al.*, 2020). These chemical compounds are used in a variety of sectors like agricultura, aquaculture, food, forestry, etc. However, pesticides shows their toxicity into the living systems (Pathak *et al*., 2022). Yadav *et al.*, (2020) has been reported that agrochemicals have residual effects in the environment causing substantial contamination of terrestrial ecosystems and poisoning human food. A rapid emergence in pesticide use began mainly after World War II with the introduction of DDT (dichlorodiphenyltrichloroethane), 2,4-D (2,4-dichlorophenoxyacetic acid), BHC (benzene hexachloride), aldrin, dieldrin and endrin because these chemicals were effective, easy to use, inexpensive, and thus enormously popular (Damalas, 2009). At present, new alternatives for pesticides that are more friendly to humans and the environment are being investigated. Extracts from some plants seem to offer that possibility, especially the use of essential oils. This work shows some aspects related to the novel biopesticide activity of essential oils.

COMPONENTS OF ESSENTIAL OILS: The volatile components of essential oils can be classified into four main groups: terpenes, benzene derivatives, hydrocarbons and other miscellaneous compounds. Monoterpenoids are the most representative molecules constituting 90% of the essential oils. They are ten carbon hydrocarbon or their related compounds such as acyclic alcohols (linalool, geraniol, citronellol), cyclic alcohols (menthol, isopulegol, terpeniol), bicyclic alcohols (borneol, verbenol), phenols (thymol, carvacrol), ketones (carvone, menthone, thujone), aldehydes (citronellal, citral), acids (chrysanthemic acid) and oxides (cineole) (Ngoh *et al.*, 1998; Tripathi *et al*., 2009). The main group is composed of terpenes and terpenoids and the other of aromatic and aliphatic constituents, all characterized by low molecular weight terpenes mainly the monoterpenes (C10) and sesquiterpenes (C15); hemiterpenes (C5), diterpenes (C20), triterpenes (C30) and tetraterpenes (C40) also exist. Aromatic compounds occur less frequently than the terpenes and are derived from phenylpropane (cinnamaldehyde, cinnamic alcohol, chavicol, eugenol, anethole, elemicine, estragole, apiole, myristicine, safrole) (Tripathi *et al*., 2009).

THE ESSENTIAL OILS AND THEIR ANTIMICROBIAL ACTIVITY: 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; Flores-Encarnación *et al*., 2016). The aromatic 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. The defense mechanisms related to secondary metabolites include flavonoids, phenols, terpenes, oils, alkaloids, lectins and polypeptides (Butkiené *et al*., 2015; Burt, 2004; Citarasu, 2010; Cowan, 1999; Flores-Encarnación *et al*., 2016). Below are some cases of the antimicrobial activity of essential oils. As antibacterial agents, the essential oils act against a wide range of pathogenic bacteria including *Salmonella typhimurium*, *Shigella dysenteriae*, *Bacillus cereus*, *Listeria monocytogenes*, *Escherichia coli* O157:H7, uropathogenic *E. coli*, *Staphylococcus aureus*. In the last decades, numerous infectious diseases have emerged and re-emerged affecting to humanity. As microbial causative agents have been the so-called 'exotic agents', which have been impacted to public health systems due to limited experience in case management and lack of appropriate resources. In most cases, these 'exotic agents' are zoonotic agents transmitted directly from animals to man or via vectors (Al-Shuneigat *et al*., 2014; Ahmed *et al*., 2017; Feldmann *et al*., 2002; Flores-Encarnación *et al*., 2018; Flores-Encarnación *et al*., 2020*b*; Hussein *et al*., 2014; Sambyal *et al*., 2017; Shuaib *et al.*, 2016; Upadhyay *et al.*, 2013). In recent years, outbreaks of different infectious diseases have been recorded worldwide. Some urban practices, such as the change in land use, the uncontrolled growth of populations, frequent contact with domesticated and wild animals, the human invasion of natural areas, the deficiency in health services (among them, the no use of vaccines) and the climate change, have been factors that promoted the emergence and re-emergence of various viral infectious diseases. In this case, the passage of certain viruses present in wild and domestic animals to man has been observed, causing the emergence of new diseases (Ahmed *et al*., 2017; Daszak *et al.*, 2001; Flores-Encarnación *et al*., 2020*b*; Ołpiński, 2012; Rahim and Uddin, 2017). Viral infections that are considered emerging today are not new. For example, the dengue fever emerged simultaneously in South-East Asia, Africa, and North America during the 18th century, whereas influenza (Spanish flu) emerged at the beginning of 20th century, killing between 25 and 40 million people in five continents. The severe acute respiratory syndrome virus (SARS), bird flu, swine flu, Ebola virus disease, Zika and Chikungunya fever have emerged in recent years (Ahmed *et al.*, 2017; Chastel, 2007; Taylor *et al*., 2001).

In that context, some examples of essential oils and the antiviral activity against pathogenic viruses has been reported. For example, Haddad *et al.*, (2019) reported on A549 human epithelial cells infected with Zika virus that the *Ayapana triplinervis* essential oil inhibited infection. They reported IC_{50} values of 38 µg mL^{-1}. Another of the viral infections with wide distribution in the world is the disease caused by the dengue virus. Dengue fever is the most prevalent human arboviral disease in tropical and subtropical regions worldwide (Douglas *et al*., 2020; Flores-Encarnación *et al*., 2020*b*; Murray *et al.*, 2013). It has been reported in vitro that the *Lippia alba* and *L. citriodora* essential oils inhibited the replication of dengue virus serotypes. The use of the *Lippia* sp. essential oils could be a potential resource for treatment of tropical disease like dengue especially in developing countries (Ocazionez *et al*., 2010). It has been reported that *L. alba* essential oil contains as major components: carvone (40-51%), limonene (30-33%) and bicyclesesquiphellandrene (7-9%). The IC_{50} of *L. alba* essential oil for dengue virus serotypes (DENV-1, DENV-2, DENV-3 and DENV-4) were also determinated: 10.1, 0.4, 32.6 and 21.1 µg mL^{-1}, respectively (da Silva *et al*., 2020; Ocazionez *et al*., 2010). On the other hand, it been reported the use of biologically active organic (also extracted from plants) with antifungal properties. Currently, studies are known that have shown that essential oils inhibit or slow the growth of yeasts and molds (Flores-Encarnación *et al*., 2022). Maness and Zubov (2019) reported that essential oils of *Rosmarinus officinalis*, *Cinnamomum verum* and *Citrus paradisi* inhibited the growth of *Trichophyton mentagrophytes*, *Microsporum gypseum* and *Rhizopus stolonifer*. These filamentous fungi produce dermatophytic fungal diseasesand are opportunistic fungi. *T. mentagrophytes* and *M. gypseum* cause athlete's foot, ringworm, and nail infections, while *R. stolonifer* is an opportunistic fungus that causes respiratory infections, sinusitis, and otomycosis (Maness and Zubov, 2019). Gucwa *et al.*, (2018) reported that *T. vulgaris*, *Citrus limonum*, *Pelargonium graveolens*, *Cinnamomum cassia*, *Ocimum basilicum*, and *Eugenia caryophyllus* essential oils showed both fungistatic and fungicidal activity toward *Candida albicans* and *C. glabrata* isolates, resulting that *C. cassia* essential oil have the highest activity. Different ways have been proposed in which essential oils affect the growth or proliferation of microorganisms. It has been reported that essential oils destabilize the bacterial cell architecture, leading to the breakdown of membrane integrity and increased permeability, which disrupts many cellular activities, including energy production (membrane-coupled), membrane transport, and other metabolic regulatory functions (Flores-Encarnación *et al*., 2020*a*; Oussalah *et al*., 2006; Saad *et al*., 2013; Swamy *et al*., 2016). In the case of viruses, some mechanisms of action of essential oils against viruses have been described, such as the herpes simplex virus-2 (HSV2). So, the compounds of essential oils exhibit direct virucidal activity to inhibit intracellular replication or interacting with viral particles, thus inhibiting cell binding and adsorption (Schnitzler, 2019). The mechanism of action of the compounds consists mainly in the direct inactivation of the extracellular HSV2 particles together with a lesser spread of the virus from cell to cell, limiting the production of viral progeny (Flores-Encarnación *et al*., 2020*b;* Toujani *et al.* 2018). Gucwa *et al*., (2018) reported that *T. vulgaris*, *Citrus limonum*, *Pelargonium graveolens*, *Cinnamomum cassia*, *Ocimum basilicum*, and *Eugenia caryophyllus* essential oils showed both fungistatic and fungicidal activity toward *Candida albicans* and *C. glabrata* isolates. This study showed that *T. vulgaris* and *C. limonum* affected the cell membranes; *T. vulgaris* produced a potassium ion efflux. In addition it was observed that all of the tested oils showed the ability to inhibit the transition of yeast to mycelium form. Candidiasis (frequently caused by *C. albicans*, *C. glabrata*, *C. tropicalis*, *C. krusei*, or *C. parapsilosis*) is associated with the formation of biofilms on the surface of medical devices and tissues (Feyaerts *et al*., 2018; Ramage *et al*., 2006). Rajkowska *et al.*, (2019) demonstrated that clove and thyme essential oils can be efficiently used preventing the formation of biofilm in abiotic surfaces (glass, polyethylene terephthalate, polypropylene) by *Candida* sp.; clove and thyme essential oils showed anti-biofilm activity.

THE BIOPESTICIDE ACTIVITY OF ESSENTIAL OILS

Pests such as weeds, pathogens and insects represent a problem for agricultural crops since they significantly reduce crop production (from 25 to 50%) (Batish*et al.*, 2008). So, to protect the agricultural crops use significant amounts of synthetic pesticides around the world. However, the excessive use of synthetic pesticides in crop fields, urban environment and water bodies (to eliminate harmful pests) has resulted in an increased risk of pesticide contamination, in addition to the emergence of resistant pests and the toxicological consequences for human health, including environmental contamination. Currently, natural pesticides are being investigated that are more friendly to the environment and few effects on human health (Batish *et al*., 2008). In this context, aromatic plants and their essential oils have been used since antiquity as flavorings (condiments or spices), as well as in fragrances, medicines, as antimicrobial agents (as described above) (Daferera *et al*., 2003; Flores-Encarnación *et al*., 2016). Essential oils have also been reported to be good insect repellents or insecticides and have served to protect stored products against pests (Bakkali *et al.*, 2008; Dorman and Deans, 2000; Isman and Machial, 2006). Therefore, these organic sources have been proposed as a valuable alternative to synthetic pesticides, since they do not produce adverse effects on the environmentand cause less harm to human, animal health and to habitats and the ecosystem (Bakkali *et al.*, 2008; Isman, 2000; Isman and Machial, 2006; Nollet

and Rathore, 2019). Currently, there is need to research novel, highly selective and easily degradable chemicals. These natural biopesticicides could be crude extracts or essential oils obtained from any plant part and are called "green pesticides". The term "green pesticide" includes all natural materials that can reduce the pest population (Mossa, 2016). These are derived from organic sources which are considered environmentally friendly and cause less harm to human, animal health and to habitats and the ecosystem (Kumar *et al*., 2022; Nollet and Rathore 2019). Essential oils have been explored for repellent, fumigant, larvicidal and adulticidal activities for pest control. The essential oils can be inhaled, ingested or skin absorbed by insects. Plants from the *Myrtaceae*, *Lamiaceae*, *Asteraceae*, *Apiaceae*and *Rutaceae* families are selected for their anti-insect activities, such as Lepidoptera, Coleoptera, Diptera, Isoptera, and hemiptera. Essential oils have been studied for their repellent, fumigant, larvicidal and adulticidal properties against insects of the previous orders (Kumar*et al*., 2022; Tripathi *et al*., 2009). Nebapure *et al.* (2022) reported the toxicity of oil-in-water formulations of different essential oils: pine, lemongrass, geranium, eucaliptus, palmarosa and citral, against *Bemisia tabaci* (polyphagus whitefly pest). Palmarosa oil was found to possess highest contact toxicity (LC_{50} and LC_{90} values of 0.241 and 0.658%, respectively, at 24 h and 0.142 and 0.398% at 48 h, after exposure). Other authors have reported that essential oil of *Ruta chalepensis* (*Rutaceae*) was a larvicidal effect against larvae of *Orgyia trigotephras* (a phytophagous insect), resulting a mean time of mortality of 1.40 min (flower oil) and 1.27 min (leaf oil) for the third instar larvae (at 0.5% essential oil in ethanol vol/vol) (Akkari *et al*., 2015; Fierascu *et al*., 2020). Essential oil of *Dracocephalum kotschyi* Boiss (with high monoterpene content) was an efficient insecticide against *Myzus persicae* Sulz. (an aphid causing major losses to the peach cultures), with LC_{50}value of 0.27 µL/L after 72 h and LC_{90} of 2.35 µL/L after 72 h (fumigant) (Fierascu *et al*., 2020; Jalaei *et al*. 2015). The main benefit of natural pesticides is that they provide residue-free food, a safe environment and affect only target insects and do not have considerable negative effects on the beneficial insects such as pollinators and natural enemies (Isman, 2006). Sayed *et al*., (2022) reported that *Mentha piperita*, *Mentha longifolia*, *Salvia officinalis*, and *Salvia rosmarinus* essential oils were natural aphicides, repellent, and deterrent against *Aphis punicae* (aphid), and they are safe for important insect predators (as *Coccinella undecimpunctata*).

In another study was reported that thymol was the most toxic essential oil component to adult males of the German cockroach, *Blattella germanica* (L.) (Dictyoptera: *Blattellidae*), with a LD_{50} value of 0.07mg per cockroach. *Trans*-cinnamaldehyde was the most toxic essential oil component to adult females with a LD_{50} value of 0.19mg per cockroach, while (+)-α-pinene was the least toxic essential oil component to different stages of the German cockroach (Phillips *et al.*, 2010). Zibaee and Khorram (2015) determined toxicity and knockdown effect by *Eucalyptus globulus* and *Rosmarinus officinalis* essential oils and their mixed formulation on *Periplaneta americana* (L.), *Blattella germanica* (L.), *Supella longipalpa*, *Culex pipiens*, *Anopheles stephensi* and *Musca domestica*. They reported that all essential oils were toxic to cockroaches, mosquitos and housefly species. At present, various works are known that refer to main applications of the essential oils as insecticides, herbicides, acaricides, nematicides (Fierascu *et al.*, 2020). However, there is much to study about essential oils, especially their novel applications as biopesticides and their mechanisms of action.

CONCLUSION

The essential oils are substances of plant origin with novel properties and applications. These substances have been known since time immemorial, however at present they are the subject of study in the world due to their multiple uses in different fields of knowledge. Especially, essential oils and their components have aroused interest as possible biopesticides because they represent a very friendly alternative to the environment and to the human and animal health, in order to combat different pests.

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