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Review Article

PROMISING INSECTICIDAL AND ANTIBACTERIAL AGENTS FROM SOME ESSENTIAL OILS: A MINI-REVIEW

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ABSTRACT
The role of essential oils in the improvement of health and lifestyle of mankind is well known since ancient civilizations. The modern urbanization has reproduced numerous synthesized chemical compounds, such as insecticides and antibacterial drugs, which revealed serious environmental and health hazards. Interests have recently returned back to natural products as competitor alternatives. Numerous scientific reports represented multiple benefits of essential oils as an insect repellent, insecticidal, antibacterial, antifungal, antiviral, antioxidant, antitumor and many biomedical activities, butting into consideration the relative safety and environmental advantages from the use of these natural products compared to the synthesized chemicals. This mini-review presents an overview of essential oils reported to have promising efficacy against insect pests and bacterial pathogens, in particular. Essential oils are a promising source for new natural bio-active molecules with no or minimum side effect.

Keywords*: Insecticides, Medicinal Plants, Essential Oils, Antibacterial, Antibiotics*

INTRODUCTION
Essential oils have been used since ancient times as flavors and fragrances and cosmetics; they are also extensively used in aromatherapy and phytomedicine. Today, there is a growing demand on essential oils all over the world and traded at good prices, which represented several billions of American dollars (Do et al., 2015). Essential oils are produced by aromatic plants as secondary phytochemical metabolites to protect the plant and attract or repel insects, these oils characterized by distinctive volatile fragrant odor, which could easily obtained by hydro-distillation; Essential oils are very complex mixtures, it is mainly consists of a great number of constituents, about 20-60 compounds, but only few components are present in high concentrations (20-70%) and the others are mostly found at low or trace amounts, although terpenes and terpenoids were amongst the major compounds of most essential oils studied (Bakkali *et al.,* 2008). Various essential oils were screened for their biological activities and reported significant antibacterial, antifungal, antiviral, antioxidant, anti-inflammatory, anti-tumor, anti-dandruff, anti-lice, insect/mosquito repellent action, spasmodic action, hormonal action and many more (Ali *et al.,* 2015). Moreover, many chemical constituents of pesticides have serious side effects, their residues are accumulated in the plant and animal tissues, soil, water and air which lead to toxicity, pathological alterations, morbidity and mortality (Sahai, 2013). On the other side, the chemical constituents of antimicrobial drugs such as antibiotics are accumulated in animal and human tissues and environment, which led to direct and indirect hazards, besides its obvious role in developing new drug-resistant pathogens (Larsson, 2014). This mini-review aimed to highlight the importance of essential oils as promising natural pesticides and as antimicrobial drugs.

Harmful Effects of Chemical Pesticides
Various insecticides are used to control pests that infest economic cultivated plants (Alewu and Nosiri, 2011). Chemical insecticides are classified according to toxicological effect, chemistry, and mode of action. In regard to penetration way, they could be classified according to whether ingestion through the stomach, penetration of the cuticle or inhalation such as fumigants. Organophosphates, carbamates and chlorinated hydrocarbons are the main groups of the synthetic insecticides. The most widely known

organophosphate compounds are malathion, parathion, diazinon and dichlorvos. Carbamates include various compounds such as carbamyl, bendiocarb and carbofuran. Chlorinated hydrocarbons considered as the largest and most multiuse group of insecticides including dichlorodi-phenyltrichloroethane (DDT), dieldrin, endo-sulfan, heptachlor, dicofol, chlordane, heptachlor, and endrin (Turusov *et al.*, 2002; Bate, 2007; Pedigo and Rice 2008; Van den Berg, 2009). Exposure to chemical pesticides through inhalation, skin or ingestion is associated with harmful effects for human health and the environment (Hayes et al., 2006; Zheng *et al.*, 2016). Furthermore, residues of pesticides could be metabolized, stored, or bioaccumulated in animal and human body fat. Additionally, pesticide residues have been detected in water, refreshments, and animal feeds. Therefore, long term exposure to chemical pesticides can result in death (Gunnell *et al.*, 2007; Chourasiya *et al.*, 2015; Pirsaheb *et al.*, 2015).

Essential Oils as Natural Insecticides

Due to chronic health effects and environmental risks that have been associated with exposure to chemical pesticides, researchers realized the urgent need for a new concept in insect pest control. Essential oils considered as bio-insecticides as well as an alternative to chemical insecticides for insect pest management. Essential oils have insecticidal, antifeedant and repellent activities against a wide range of agricultural pests. It consists of various aromatic plants that possess volatile components produced as secondary metabolites (Bassole *et al.*, 2011; Regnault-Roger *et al.*, 2012). The volatile compounds of essential oils can be divided into four classes: terpenes, hydrocarbons, benzene derivatives and miscellaneous compounds (Breitmaier, 2006; Zuzarte, and Salgueiro, 2015). Many researchers reported that the essential oils can disrupt the insect nervous system in different ways which can cause mortality (Enan, 2001; Priestley *et al.*, 2003; Lee *et al.*, 2004). With reference to (Table 1), which is showing some of these promising essential oils, that could be utilized as natural insecticides against specific insects. On the other side, insect repellents from natural essential oils are well known since ancient civilizations, essential oils are currently marketed in different pharmaceutical forms against many annoying household pests such as ants, mosquitoes, ticks and flies (Figure 1).

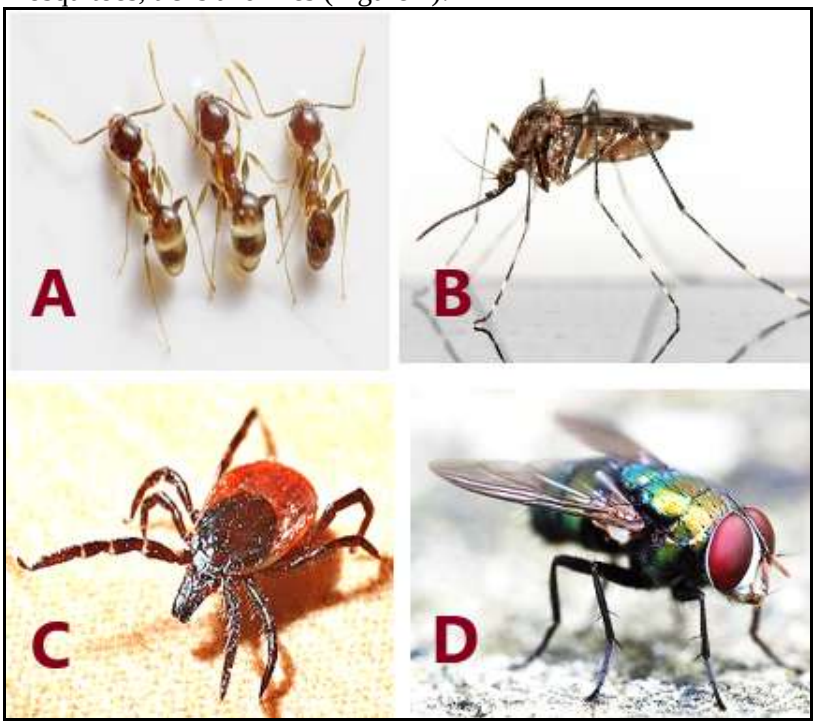

Figure 1: Examples of some household pests repelled by various essential oils
Photos represents: A=Ants, B= Mosquitoes, C= Ticks, D= Flies (Source of free photos: https://pixabay.com)

Table 1: Examples of some essential oils tested for their insecticidal activity

Source of essential oil	Tested insect	Insecticidal concentration	Reference
Cymbopogon citratus	*Spodoptera frugiperd*	0.19 µL/cm²	Knaak (2013)
Cymbopogon nardus	*Acharia fusca*	0.002-8 µL/g	Hernández-Lambraño *et al.*, (2014)
Cymbopogan citratus, Eucalyptus globulus	*Musca domestica*	0.66 µl/cm2	Chauhan *et al.*, (2016)
Cymbopogan citratus, Eucalyptus globulus	*Anopheles stephensi*	44.66 ppm	Chauhan *et al.*, (2016)
Artemisia absinthium	*Bemisia tabaci*	0.157 ppm	Ibrahim and Mostafa (2018)
Carum carvi	*Spodoptera littoralis*	41.45 µl/l air	Ben Khalifa *et al.*, (2018)
Brassica alba	*Cydia pomonella*	0.422 mg ml–1	Konecka *et al.*, (2018)
Santolina chamaecyparissus	*Myzus persicae*	0.34%	Czerniewicz *et al.*, (2018)
Artemisia lavandulaefolia	*Plutella xylostella*	0.045 µL per larva	Huang *et al.*, (2018)
Cascabela peruviana	*Helicoverpa armigera*	103.19 ppm	Deepa *et al.*, (2018)

Negative Impacts of Antibiotics

One of the famous antimicrobial drugs used against bacterial pathogens are antibiotics, which are either natural, semi-synthetic or synthetic molecules, the latter is altered less biodegradable. Huge quantities of synthetic or semi-synthetic antibiotics come from hospitals and pharmaceutical industry dumps reach wastewater treatment plants in active form and accumulated in the environment and uptakes by plants and soil microorganisms and subsequently enters the life cycles (Kumar *et al.*, 2005 and Louvet *et al.*, 2010). These antibiotics are one of the serious micro-contaminants accumulated in soil and water for a very long time and threaten ecosystems as well as human and animal life. Moreover, antibiotics are negatively affected the natural microbial communities in ecosystems and accordingly disturbed the environmental balance (Grenni *et al.*, 2018). Semi-synthetic β-lactam antibiotics are one of these difficult to decay molecules and considered as dangerous pollutants (Fernandez-Lafuente *et al.*, 2002). Moreover, the growing phenomenon of antibiotics resistant pathogen is considered as an international dilemma, bacterial pathogens such as *Staphylococcus aureus*, *Klebsiella pneumoniae*, non-typhoidal *Salmonella* and *Mycobacterium tuberculosis* are now counted as serious global public health threats and they have developed resistance against almost all known antibiotics and accordingly innovative approaches are badly needed for the development of new antibacterial drugs limit this global health crisis (Prestinaci *et al.*, 2015).

Essential Oils as Natural Antibacterial Drugs

It is well known that there are some medicinal plants have the ability to inhibit the growth pathogens due to the presence of secondary metabolites. Aromatic medicinal plants are rich in these antibacterial metabolites in a form of essential oils. The chemical profile of essential oils is greatly depending on many factors, such as the quantity and quality, of bioactive compounds, which are depending on environmental conditions like climate, soil, plant organ, age of plant and seasons, also stereochemical properties of these metabolites and the type of extraction have their effects (Masotti *et al.*, 2003). Some of these promising antibacterial essential oils are represented in (Table 2). Amongst them are the essential oils of cinnamon (*Cinnamomum zeylancium*), which are extensively studied and reported as efficient antibacterial agent, (Nabavi *et al.*, 2015) cited that at least 45 scientific papers have been published on the essential oils of Cinnamon in 5 years (from 2010 up to 2015) showed high antibacterial activity against different Gram-negative and Gram-positive bacteria. Essential oils from two Thyme species (*Thymus broussonetii* and *Thymus maroccanus*) exhibited considerable antibacterial activity against 10 different nosocomial infections bacteria (Fadli et al., 2012). In Brazil, 24 multi-drug resistant strains related to six different bacterial species isolated from biological materials of patients suffering from nosocomial infections were highly inhibited by the essential oil of *Origanum vulgare* L. (Lamiaceae) (Costa *et al.,* 2009). Four standard bacterial strains (*Bacillus subtilis* NCTC 8236, *Staphylococcus aureus* ATCC 25923, *Escherichia coli* ATCC 25922 and *Pseudomonas aeruginosa* ATCC 27853) revealed significant susceptibility to the essential oil of clove (*Syzygium aromaticum*) (Fagere and Al Magboul, 2016). *Listeria monocytogenes* is a difficult-to-treat pathogen, it is responsible for severe infections in human and many animal species. This serious pathogen was found to be sensitive to the essential oil of the Wormwood (*Artemisa arbrescens*) (Militello *et al.*, 2011). The essential oil of Lemongrass Lemon grass (*Cymbopogon citratus*) was found effective against all the test gram-positive and Gram-negative bacteria except *Pseudomonas aeruginosa* (Naik et al.,2010). Essential oil of sage (Salvia officinalis L.) grown in Serbia showed active antibacterial effects against Bacillus subtilis, Staphylococcus aureus, *Escherichia coli* and *Salmonella enteritidis* (Miladinović and Miladinović, 2000). Essential oil of *Trachyspermum ammi* (L.) was tested against *Staphylococcus aureus, Enterococcus faecalis, Escherichia coli* and *Pseudomonas aeruginosa*, as well as two isolates from infected Poultry, namely *Escherichia coli* and *Salmonella typhimurium*, the oil revealed high antibacterial activity against all tested bacteria (Omidpanah et al., 2016). Essential oils from an Argentinian plant known in as Ajenjo (*Artemisia echegarayi*), high efficacy of essential oils against food-borne pathogenic bacteria with low minimum inhibitory concentration (MIC) and recommended as promising alternative as a natural food additive (Laciar *et al.,* 2009). Essential oils of *Commiphora myrrha* (Myrrh), family (Burseraceae), native to Northeastern Africa exhibited noticeable antibacterial activity against Five pathogenic bacteria, namely *Staphylococcus aureus* (ATCC13565) *Listeria monocytogenes* (EMCC 1875), *Bacillus cereus* (EMCC1080), *Escherichia coli* O157:H7 (ATCC51659) and *Salmonella typhimurium* (ATCC 25566) (Mohamed et al., 2016). Ginger (*Zingiber officinale*) is used for the treatment of throat infections, its essential oil was found to be active against many bacterial strains, like *Staphylococcus aureus* FES-I, *Staphylococcus epidemidis*, *Eterococcus faecalis* ATCC 14506, in particular (López *et al.,* 2017). Essential oil of *Pulicaria inuloides*, which are grown in Yemen, has recorded high antibacterial activity against six strains of Listeria species: *Listeria monocytogenes* ATCC 7644, *Listeria welshimeri* ATCC 35897, *Listeria innocua* ATCC 33090, *Listeria grayi* ATCC 25923, *Listeria ivanovii* ATCC 19119 and *Listeria seeligeri* SLCC 3954 (Al-Hajj *et al.*, 2017).

CONCLUSION

From numerous reports highlighted in this study, we can conclude that there are considerable numbers of essential oils having effective activity against insect pests and pathogens. Essential oils might play an important role in pest management programs in future. The use of essential oils in the insecticidal industry can be an alternative to satisfying the increasing demand for hazardous chemical insecticides. On

Table 2: Examples of some essential oils tested for their antibacterial activity

Source of essential oil	Tested microorganism	Antibacterial dose	Reference
Cinnamon (*Cinnamomum zeylancium*)	*Salmonella typhi, Salmonella paratyphi A, Escherichia coli, Staphylococcus aureus, Pseudomonas fluorescens* and *Bacillus licheniformis*	MIC values ranged from 2.9 to 4.8 mg/mL	Naveed *et al.*, (2013)
Thyme (*Thymus broussonetii* and *Thymus maroccanus*)	Nosocomial infection – bacteria	MIC values ranged from 0.002 to 5.52 mg/mL	Fadli *et al.*, (2012)
Oregano (*Origanum vulgare*)	Multi-drug resistant bacteria isolated from nosocomial patients	MIC values ranged from 78 to 83%.	Costa *et al.*, (2009)
Clove (*Syzygium aromaticum*)	*Bacillus subtilis, Staphylococcus aureus, Escherichia coli* and *Pseudomonas aeruginosa*	MIC values ranged from 0.78 mg/ml to 1.5 mg/mL	Fagere and Al Magboul (2016)
Worm wood (*Artemisa arbrescens*)	*Listeria monocytogenes*	MIC value was 0.625 µl/mL	Militello et al (2011)
Lemon grass (*Cymbopogon citratus*)	*Staphylococcus aureus, Bacillus cereus, Bacillus subtilis, Escherichia coli* and *Klebsiella pneumoniae*	MIC values ranged from 0.06 to 0.5 %.	Naik *et al.*, (2010)
Sage (*Salvia officinalis*)	*Bacillus subtilis, Staphylococcus aureus, Escerichia coli* and *Salmonella enteritidis*	Standard disc diffusion showed zone of inhibition ragged from 14.45±0.71 to 20.20±0.84 mm.	Miladinović and Miladinović (2000)
Ajowan (*Trachyspermum ammi*)	*Staphylococcus aureus, Enterococcus faecalis, Escherichia coli, Pseudomonas aeruginosa* and *Salmonella typhimurium*	MIC values <0.02 µL/mL	Omidpanah *et al.*, (2016)
Ajenjo (*Artemisia echegarayi*)	food-borne pathogenic bacteria.	MIC values ranged from 2.4 to 75.0 µg/mL	Laciar *et al.*, (2009)
Myrrh (*Commiphora myrrha*)	*Staphylococcus aureus, Listeria monocytogenes, Bacillus cereus, Escherichia coli* and *Salmonella typhimurium*	MIC values ranged from 2 to 5 µl/mL	Mohamed *et al.*, (2016)
Ginger (*Zingiber officinale*)	*Staphylococcus aureus, Staphylococcus epidemidis* and *Eterococcus faecalis*	MIC values ranged from 0.25 to 1.0 mg/mL	López *et al.*, (2017)
Pulicaria inuloides	*Listeria monocytogenes, Listeria innocua, Listeria ivanovii , Listeria seeligeri Listeria welshimeri* and *Listeria grayi*	MIC values ranged from 5.49 to 11.55 µg/mL	Al-Hajj *et al.*, (2017)

the other side, essential oils, which are already used in aromatherapy in traditional medicine, could provide a good alternative for antibiotics, either in pure form or in synergy with regular antibiotics.
Moreover, the degradation of their byproducts is easy and do not harm the environment. This study recommends many essential oils for insect-repellents or natural insecticides against specific insects, as well as the applications of these essential oils in food technology as preservatives and pharmaceutical preparations as natural antibiotics. Encouragement is required for further research into essential oils as an effective alternative.

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