Acaricidal and insecticidal effects of essential oils against ectoparasites of veterinary importance

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Abstract: Ectoparasitism in animals has become an issue of great concern that needs to be resolved to prevent huge economic losses occurring to livestock industry all over the world. Synthetic adrugs have been playing a major role in controlling ectoparasites, but their frequent and irrational use has resulted in drug resistance to routinely used chemicals and their residual effects on food and environment. Therefore, this approach of using chemical acaricides and insecticides is losing its popularity and effectiveness in controlling ectoparasites. So, the development of alternative approaches in ectoparasite management is currently required. Among alternative protocols, plants and their essential oils have played remarkable role in controlling different ectoparasites (ticks, flies, mites, lice) of veterinary importance. Essential oils have been proved to be cheaper, more effective and safer therapeutic agents against different ectoparasites of livestock importance.

Keywords: Plants; Essential oils; Ectoparasites; Animals

Resumen: En los animales el ectoparasitismo se ha convertido en un tema de gran preocupación que debe resolverse para evitar que se produzcan grandes pérdidas económicas para la industria ganadera en todo el mundo. Los aditivos sintéticos han desempeñado un papel importante en el control de los ectoparásitos, pero su uso frecuente e irracional ha dado como resultado la resistencia a los fármacos utilizados habitualmente y efectos residuales sobre los alimentos y el medio ambiente. Por lo tanto, el enfoque basado en el uso de acaricidas e insecticidas químicos está perdiendo popularidad y efectividad en el control de los ectoparásitos. Por lo tanto, actualmente se requiere el desarrollo de enfoques alternativos en el manejo de ectoparásitos. Entre los protocolos alternativos, las plantas y sus aceites esenciales han jugado un papel notable en el control de diferentes ectoparásitos (garrapatas, moscas, ácaros, piojos) de importancia veterinaria. Se ha demostrado que los aceites esenciales son agentes terapéuticos más baratos, más efectivos y más seguros contra diferentes ectoparásitos de importancia ganadera.

Palabras clave: Plantas; Aceites Esenciales; Ectoparásitos; Animales
INTRODUCTION
Parasitic diseases account for important health hazard in man and animal in tropical countries. Ectoparasites cause serious threat to animals health and economy all over the world. They can cause annoyance, irritation, skin infection, anaemia, tick fever as well as act as a vector for various devastating diseases of livestock importance (Abbas et al., 2014; Yadav et al., 2017). Among ectoparasites, tickborne infections are recognized as most devastating because of causing huge economic losses (Chen et al., 2014; Demesse and Derso, 2015; Opara et al., 2016). Likewise, ectoparasites are of great concern due to their increasing prevalence, zoonotic potential and causing lowered animal productivity (Jabbar et al., 2015; Zahid et al., 2016; Zaman et al., 2017a; Zaman et al., 2017b).

Ectoparasites infecting various species of animals are controlled by using synthetic insecticides which is mostly practiced method throughout the world in spite of several problems like development of resistance, public concern in terms of residue in food and environment pollution (Maxwell et al., 2002; El-Seedi et al., 2017; Showler, 2017). Therefore, use of insecticides has been limited due to development of insecticidal drug resistance in ticks (Olivares-Pérez et al., 2011; Foil et al., 2004; El-Seedi et al., 2017), lice (Ellse et al., 2012), flies (Showler, 2017) and mites (Beugnet et al., 1997).

Due to resistance problems alternative options are being incorporated in strategic and integrated parasite control programs (Masood et al., 2013; Abbas et al., 2017a; Abbas et al., 2017b; Idris et al., 2017; Khan et al., 2017). Among alternatives, the use of essential oils has been an area of focused research in several countries (Álvarez et al., 2008; Khalíq et al., 2015; Liaqat et al., 2016).

Plants extracts and essential oils have been extensively used in controlling diseases of parasitic, viral and bacterial origin (Ibrahim et al., 2001; Ntalli et al., 2010; Ellse et al., 2013; Ellse & Wall, 2014; Aslam et al., 2016; Awaad et al., 2016; Chen et al., 2016; Fang et al., 2016; Sands et al., 2016; Esmacily et al., 2017; Radsetoulalova et al., 2017; Sharifi-Rad et al., 2017).

Herbal medication has become an appealing approach and it has gained great importance in tropical and subtropical regions especially in Asia and Africa (Habeeb, 2010; Fang et al., 2016; Ijaz et al., 2016; Rehman et al., 2016; Niroumand et al., 2016; Showler, 2017; Qureshi et al., 2017). Scientists and researchers all over the world have proved that the phytochemicals or essential oils obtained from different plants have ovicidal, larvicidal, adulticidal and repellent effects against ectoparasites (Abbas et al., 2014; Fang et al., 2016). Efficiency of botanical driven products and essential oils is frequently ascribed due to their main constituents which have diverse properties and positive effects (Yang et al., 2003; Cal, 2006; Birkett et al., 2011; Abbas et al., 2014; El-Seedi et al., 2017).

This review estimates the potential essential oils in controlling ectoparasites of veterinary importance with their possible mechanism of action.

Effects against Ticks
A lot of work has been done in last decade on investigating the acaricidal response of different essential oils against ticks of *Ixodidae* family (hard ticks). Essential oils of *Ageratum houstonianum* have shown remarkable effects against ticks biting goats. There was a 94.9% decrease in the counting of biting ticks on goats treated with essential oils of *Ageratum houstonianum* (Pamo et al., 2005). In an *in vitro* experiment essential oils derived from *Thymus vulgaris*, *Dorystoechas hasata* and *Mentha longifolia* were tested through larval immersion test which resulted in 99% mortality of *Rhipicephalus microplus* larvae after exposure to each oil (0.1% solution) (Koc et al., 2013). Essential oils of *Pimenta dioica* and *Cuminum cyminum* were also effective against *Rhipicephalus microplus* in 1.26% and 2.49% solution of each oil while essential oil of *Ocimum basilicum* had no larvae killing possessions, even at the quantity of 19.9% (Martinez-Velazquez et al., 2011). Essential oil of *Hypericum pytantheum* (Ribeiro et al., 2007) and *Calceolaria serrata* (Ribeiro et al., 2008) caused no effect on mortality of two species of ticks including *Rhipicephalus sanguineus* and *Rhipicephalus microplus*. In another study, the essential oils of *Melaleuca alternifolia* (Iori et al., 2005), *Satureja thymbra* (Cetin et al., 2010) and *Origanum minutiflorum* (Cetin et al., 2009) were proved to be effective against hard ticks.

In a recent *in vitro* study, essential oils of *Conyza dioscoridis*, *Artemisia herba-alba* and *Calendula officinalis* have shown high repulsive activity against hard ticks (El-Seedi et al., 2017). In another *in vivo* study protective action of *Tagetes minuta* (Asteraceae) essential oil against *Rhipicephalus microplus* was reported and results suggested that *Tagetes minuta* was greatly effective
against ticks (Andreotti et al., 2013). Previously, essential oil of Tagetes minuta essential oil proved to be 95% effective for controlling the different tick species including Rhipicephalus microplus, Rhipicephalus sanguineus, Amblyomma cajennense and Argas miniatus. The efficacy of essential oil was accessed by adult immersion and larval packet tests (Garcia et al., 2012).

The acaricidal potential of essential oils may be accredited due to the action of their volatile components and constituents (Kim et al., 2007; George et al., 2009; Cetin et al., 2010).

Effects against Mites

Essential oils are also effective against various mites infecting animals. In an in vitro study, the essential oils of plants such as Eugenia caryophyllata, Coriandrum sativum and Juniperus oxycedrus were proved to be effective against Dermanyssus gallinae (poultry red mite) and caused 99.9% mortality (Kim et al., 2004). In a recent study, essential oils derived from plants such as clove, palmarosa, tea tree, and eucalyptus species have shown potential against Sarcoptes scabiei (Iitch mite). Results of study demonstrated that essential oils of these plants are potential alternative products to treat Sarcoptes scabiei infections in animals and humans (Fang et al., 2016).

In another trial in which mites were permitted interaction with essential oil of Leptospermum scoparium in closed and open chambers which showed good results by causing 29.9% mortality rate in open chambers while 80% mortality rate in closed chambers (George et al., 2009). Likewise, higher mortality was observed after treatment of essential oil of Thymus vulgaris in closed chambers as compared to open chambers (George et al., 2009). It has been shown that volatile characteristics in Thymus vulgaris may be enough to resist Dermanyssus gallinae for up to 10-15 days (George et al., 2009). Essential oil of Lavandula angustifolia caused 70% mortality of mites in an in vitro assay (George et al., 2008).

Some other in vitro studies have demonstrated that essential oil of Lavandula angustifolia and most of its ingredients have shown potential against Psoroptes cuniculi (Perrucci et al., 1996). Furthermore, essential oil of Cinnamomum verum (cinnamon) leaf have been revealed to have great acaricidal effectiveness against Psoroptes cuniculi on rabbits (Fichi et al., 2007). In an in vitro trial among four tested commercially available monoterpenes (Sigma–Aldrich, Milan, Italy) geraniol caused 100% mortality of Otodectes cynotis (dog ear mite) whereas limonene, p-cymene and α-pinene were proved to be less effective (Traina et al., 2005).

Different experiments have shown that acaricidal and insecticidal efficacy of essential oils varies due to difference in composition of essential oil and concentration of its active components that varies in different varieties of same plant and also part of plant (leaves, roots) (George et al., 2010). For example, essential oils obtained from different varieties of Lavandula angustifolia showed marked differences in toxicity against D. gallinae (George et al., 2010). Inconsistency in oil composition or fractions in different varieties and parts of plants is an inherent problem. Such differences are important because the precise composition of an essential oil may determine its acaricidal efficacy (Na et al., 2011).

Furthermore, chemical composition of essential oils can also vary according to various factors such as season (for example before or after flowering), soil conditions including its type and water availability (Andrade et al., 2011). Another important factor that effects the chemical composition of essential oils is genetic composition of the plant which is in accordance with plant variety. All such factors including genetic and epigenetic factors affect the biochemical synthesis of essential oils in a particular plant. So, the same species of plant with different chemical composition of essential oil may produce different biological and therapeutic effects (Sangwan et al., 2001).

Effects against Flies and Fleas

Essential oils have been also effective against various flies and fleas infecting different species of animals. In in vitro test essential oil of Mentha piperita (peppermint) was found to be effective against larvae of the Musca domestica (house fly) (Morey and Khandagle, 2012). In another study nuisance flies such as Stomoxys calcitrans, Hippobosca equina and Musca domestica were declined and repelled on cattle cured with essential oils of Mentha piperita, Matricaria chamomilla and Cinnamomum camphora (Khater et al., 2009). Repulsive properties of essential oil of Myrica gale were evaluated against Culicoides impunctatus (biting midge) and results showed that essential oil of Myrica gale have repulsive effects against Culicoides impunctatus.
Essential oil of Nepeta cataria also showed good response against Stomoxys calcitrans in an in vitro study (Zhu et al., 2012).

In another study essential oils including basil, cinnamon, citronella and thymus essential oils showed larvicidal activity against Anopheles dirus and Aedes aegypti mosquito (Pitasawat et al., 2007).

Various experiments have shown that essential oils play important role in controlling flies being responsible for myiasis on animals such as Lucilia cuprina (Callander & James, 2012) and Synthesiomyia nudiseta (Khalaf et al., 2009). In an in vitro study conducted on essential oil of Melaleuca alternifolia (tea tree), major repulsive properties to larva of Lucilia cuprina have been recorded (Callander & James, 2012). Essential oils are also effective against various fleas infecting animals. It has been observed that essential oil of the Citrus sinensis (citrus) oil is harmful to Ctenocephalides felis (cat flea) (Collart & Hink, 1986). Furthermore, essential oils containing carvacrol and its derivatives caused death of flea in an in vitro study (Panella et al., 2005).

In an experiment, insecticidal activity of essential oils from Origanum onites, Satureja thymbra and Myrtus communis was evaluated against different insects. Among all tested the essential oils of Origanum onites and Satureja thymbra were effective causing 100% mortality of insects (Ayvaz et al., 2010).

**Effects against Lice**

Essential oils are also effective against various types of lice infecting animals. Various in vitro and in vivo trials have shown remarkable results against lice of veterinary importance. In an in vitro study, effectiveness of essential oil of Melaleuca alternifolia (tea tree) was evaluated against Bovicola cellatus (chewing lice). The essential oils showed their antilice activity in terms of high mortality (Talbert & Wall, 2012). Different in vitro assays have displayed that usage of 1% quantity of tea tree caused 100% mortality of Bovicola ovis (sheep lice) (Callander and James, 2012). In another in vitro study, essential oil of Cinnamomum camphora (camphor) proved to be the lethal to Haematopinus tuberculatus and caused ovicidal action on its eggs (Khater et al., 2009).

Essential oil of Lippia multiflora proved to have excellent potential against body lice, head lice and scabies mites, with overall efficacy exceeding as compared to synthetic drugs tested (Oladimeji et al., 2000).

**Mechanism of action of Essential Oils**

Acaricidal and insecticidal effects of essential oils are largely associated with the presence of bioactive constituents (Boldbaatar et al., 2014). Many botanical oils and their extracts are composed of more than one bioactive compound that can exert different modes of action against ectoparasites (Showler, 2017). Many studies have revealed that constituents of essential oils have harmful effect on nervous system of ectoparasites. For example, terpinen-4-ol, high in concentrations in tea tree oil, inhibits release of acetylcholinesterase which is essential for insects for their activity and synaptic transmission (Bakkalai et al., 2008; Lopez & Pascual-Villalobos, 2010). Different compounds of essential oils are also known to act on Octopamine (circulating-neuromodulator) and its disruption results in complete breakdown of nervous system in insects (Hollingworth et al., 1984). Furthermore, essential oils are hydrophobic in nature and cause water stress in insects by blocking the spiracles resulting in suffocation and distressing the cuticular waxes (Burgess, 2009).

Different studies have shown that essential oils components act synergistically. This may occur because some oil components aid cellular accumulation and absorption of other toxic components (Yang et al., 2003; Cal, 2006). Although several hypotheses for this have been proposed, the underlying mechanism has not been fully elucidated so far. Synergistic activity observed has long been speculated to be obtained via complex effects in several targets due to multiple modes-of-action by different components (Tak & Isman, 2017). However, despite this complexity in their modes-of-action, the synergistic or antagonistic effects in essential oil-based insecticides seem to depend upon concentration of major constituents of particular essential oil (Tong & Coats, 2012).

Mostly essential oils are rapidly absorbed after dermal or oral administration and cross the blood-brain barrier and interact with receptors in the central nervous system. Components of essential oils are fat soluble and have the ability to permeate the membranes of the skin and act on targets organs (Adorjan & Buchbauer, 2010). Most essential oil components are metabolized and either eliminated by the kidneys in the form of polar compounds (Kohler et al., 2000). The same happens with thymol,
carvacrol, limonene and eugenol. After their oral administration, sulphate and glucuronide forms have been detected in urine and in plasma respectively (Michiels et al., 2008). Due to their volatility nature and fast metabolism of its active compounds there is a minimum risk of accumulation in body tissues (Kohlert et al., 2002).

Essential oils are highly complex mixtures of volatile compounds (Shibamoto, 2010), including hydrocarbons (e.g. limonene, pinene), acids (e.g. benzoic acid, geranic acid), alcohols (e.g. santalol, linalol), aldehydes (e.g. citral, cuminal), ketones (e.g. camphor), lactones (e.g. bergaptene), phenols (e.g. eugenol), phenolic ethers (e.g. anethole), oxides (e.g. 1,8 cineole) and esters (e.g. geranylacetate) (Andrade et al., 2011).

Limitations of using essential oils

No doubt essential oil have wide potential uses but, their use remain limited due to toxic effects and other undesirable effects (Yang et al., 2005). Essential oils also deteriorate the cell membrane and cell wall structure cytoplasmic membranes and organelles of cell including mitochondria and peroxisomes (Bakkali et al., 2008). Essential oils disturb the depolarization of mitochondrial membrane in cell by altering ion channels and effect ATP synthesis (Vercesi et al., 1997). Essential oils such as thymol and carvacol have been proved to be lethal for the intestinal cells of mucosa layer due to lipophilic and hydrophobic nature (Giannenas et al., 2003). Furthermore, essential oils separated from Chinese as well Egyptian plants have been reported to cause fumigant toxicity (Fu et al., 2013). It should also be taken into account that essential oils and their components could cause allergic reactions and symptoms (De Groot & Schmidt, 2016).

Table No. 1

<table>
<thead>
<tr>
<th>Scientific Name</th>
<th>Common Name</th>
<th>Ectoparasite</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ageratum conyzoides L</td>
<td>Goat weed</td>
<td>Ticks</td>
<td>Kumar et al., 2016</td>
</tr>
<tr>
<td>Allium sativum L</td>
<td>Garlic</td>
<td>Mites</td>
<td>George et al., 2010</td>
</tr>
<tr>
<td>Artemisia absinthium L</td>
<td>wormwood</td>
<td>Ticks</td>
<td>Jaenson et al., 2005</td>
</tr>
<tr>
<td>Artemisia herba-alba Asso</td>
<td>Asso</td>
<td>Ticks</td>
<td>El-Seedi et al., 2017</td>
</tr>
<tr>
<td>Azadirachta indica A. Juss</td>
<td>Neem</td>
<td>Ticks</td>
<td>Nawaz et al., 2015</td>
</tr>
<tr>
<td>Brassica juncea (L) Vassili Matveievitch Czarnajew</td>
<td>Mustard</td>
<td>Mites</td>
<td>Kim et al., 2004</td>
</tr>
<tr>
<td>Calendula officinalis L</td>
<td>Marigold</td>
<td>Ticks</td>
<td>El-Seedi et al., 2017</td>
</tr>
<tr>
<td>Cleome hirta (Klotzsch) Oliv</td>
<td>Purple cleome</td>
<td>Ticks</td>
<td>Ndungu et al., 1999</td>
</tr>
<tr>
<td>Syzygium aromaticum (L) Merr. &amp; L.M.Perry</td>
<td>Clove</td>
<td>Mites</td>
<td>Kim et al., 2004</td>
</tr>
<tr>
<td>Cleome gynandra L</td>
<td>Stinkweed</td>
<td>Ticks</td>
<td>Lwande et al., 1999</td>
</tr>
<tr>
<td>Laurus nobilis L</td>
<td>Bay</td>
<td>Mites</td>
<td>Macchioni et al., 2006</td>
</tr>
<tr>
<td>Lippia gracilis Schauer</td>
<td>Zapania Lam</td>
<td>Ticks</td>
<td>Cruz et al., 2013</td>
</tr>
<tr>
<td>Melaleuca alternifolia Maiden &amp; Betch ex Cheel</td>
<td>Tea tree</td>
<td>Mites</td>
<td>Magi et al., 2006</td>
</tr>
<tr>
<td>Ocimum basilicum L</td>
<td>Sweet Basil</td>
<td>Ticks</td>
<td>Veeramaniet al., 2014</td>
</tr>
<tr>
<td>Origanum bilgeri P.H.Davis</td>
<td>Oregano</td>
<td>Ticks</td>
<td>Kocet et al., 2013</td>
</tr>
<tr>
<td>Pimenta dioica L</td>
<td>Allspice</td>
<td>Ticks</td>
<td>Martinez-Velazquez et al., 2011</td>
</tr>
<tr>
<td>Tagetes minuta L</td>
<td>Wild marigold</td>
<td>Ticks</td>
<td>Andreottiet al., 2013</td>
</tr>
<tr>
<td>Thymus vulgaris L</td>
<td>Thyme</td>
<td>Mites</td>
<td>George et al., 2009</td>
</tr>
</tbody>
</table>
### Table No. 2

**Major constituents of some important essential oils**

<table>
<thead>
<tr>
<th>Scientific Name</th>
<th>Essential Oil</th>
<th>Major Constituent</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Thymus vulgaris</em> L</td>
<td>Thyme</td>
<td>Carvacrol, Thymol, Borneol</td>
<td>Fadli et al., 2011</td>
</tr>
<tr>
<td><em>Thymus pulegioides</em> L</td>
<td>Thyme</td>
<td>Geraniol</td>
<td>Miladinovic et al., 2014</td>
</tr>
<tr>
<td><em>Origanum vulgare</em> L</td>
<td>Oregano</td>
<td>Cymenol</td>
<td>Rosato et al., 2010</td>
</tr>
<tr>
<td><em>Origanum majorana</em> L</td>
<td>Marjoram</td>
<td>4-Terpinenol</td>
<td>El-Hosseiny et al., 2014</td>
</tr>
<tr>
<td><em>Salvia officinalis</em> L</td>
<td>Sage</td>
<td>1,8-Cineole</td>
<td>El-Hosseiny et al., 2014</td>
</tr>
<tr>
<td><em>Satureja montana</em> L</td>
<td>Savory</td>
<td>Geraniol</td>
<td>Miladinovic et al., 2014</td>
</tr>
<tr>
<td><em>Ocimum basilicum</em> L</td>
<td>Basil</td>
<td>Linalool</td>
<td>Silva et al., 2015</td>
</tr>
<tr>
<td><em>Aniba rosaeodora</em> Ducke</td>
<td>Rosewood</td>
<td>Terpinen-4-ol</td>
<td>Rosato et al., 2010</td>
</tr>
<tr>
<td><em>Melaleuca Alternifolia</em> Maiden &amp; Betchex Cheel</td>
<td>Tea tree</td>
<td>Citronellol</td>
<td>Rosato et al., 2010</td>
</tr>
<tr>
<td><em>Pelargonium graveolens</em> L’Her</td>
<td>Geranium</td>
<td>Viridiflorol, Spathulenol, Elemol</td>
<td>Rodrigues et al., 2010</td>
</tr>
<tr>
<td><em>Zanthoxylum articulatum</em> Engler</td>
<td>Limão-bravo</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Mentha piperita</em> L</td>
<td>Peppermint</td>
<td>Menthol &amp; menthone</td>
<td>Sala, 2011</td>
</tr>
<tr>
<td><em>Azadirachta indica</em> A. Juss</td>
<td>Neem</td>
<td>Hexadecanoic acid, Oleic acid, octadecanoic acid, 4-octylphenol</td>
<td>Kurose &amp; Yatagai, 2005</td>
</tr>
</tbody>
</table>

**Concluding Remarks**

On the basis of previous and recent research on essential oils against ectoparasites, it is proved that essential oils are effective in controlling ectoparasites of livestock importance. The essential oils should be considered as an alternative to chemical insecticides thus delaying or averting resistance. Essential oils can act as the best alternative in the treatment of ectoparasite infections. However, most of the studies reported in this review article are not so well designed and comprehensive and based on just in vitro trials in laboratory conditions, therefore, further extensive in vivo trials and experiments are needed for formulation and standardization of herbal products from these essential oils to be used in field practices.

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