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ROLE OF ESSENTIAL OILS/VOLATILE OILS IN POULTRY PRODUCTION - A REVIEW ON PRESENT, PAST AND FUTURE CONTEMPLATIONS

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ABSTRACT

Nowadays, poultry production has high demand worldwide. For this purpose, performance parameters are maximized, for example, fast-growing of chicken with low usage of feed and with the better health status of the flock. This increasing demand has led to the use of many antibiotic-free products. There is an increased pressure to decrease the amount of antibiotics used as bacteriostatic or bactericidal agents for poultry, so there is an utmost need for unconventional resolutions to sustain the productivity and efficacy of poultry. Among the substitutions, essential oils (EOs) have a prodigious potential and are usually thought to be natural, free from hazardous deposits and chemicals, and less toxic. EOs are plant-based extracts, and there are about 3,000 known EOs, out of which 300 are identified as useful and commercially important. It is proven that EOs have abundant in vitro and in vivo research to yield special effects on numerous pathogens, including bacteria, viruses, fungi, and parasites. The current review provides information on the fundamentals of EOs, the anti-oxidation and immunomodulatory characteristics, the growth-promoting effects, and the activities of EOs against a variety of pathogens in animals/poultry.

***Keywords*:** Essential oils, Broiler/layer, Immunity, Antibiotics, Pathogens

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1. INTRODUCTION

In modern years, natural substances such as biologically active plant elements are usually considered better and used in the invention of drugs and foundations in agriculture especially in the European states like Japan and USA (Jafari et al. 2011). Some of these natural substances are known as EOs (also as volatile oils) which are aromatic in nature and are oily extractions of different parts of plants e.g., roots, flower, bud, seeds, leaves, bark and wood etc. (Nazzaro et al. 2013). There are numerous characteristics of volatile oils provided by the literature for example immunostimulatory, antiviral, digestive stimulant, antibacterial, antifungal and antioxidant (Solorzano-Santos and Miranda-Novales 2012; Bharti et al. 2012; Mahboubi et al. 2013; Bento et al. 2013; Alali et al. 2013; Krishan and Narang 2014; Fallah and Mirzaei 2016; Assiri et al. 2016). The biochemical composition of EOs talks about mode of action and the characteristics of oils. Nazzaro et al. (2013) described possible ways of action of the EOs and/or their elements and demonstrated the possible cell targets of their antimicrobial activity. However, each of these acts cannot be judged by distinct events but instead may be an outcome of the other event (Fig. 1). There are many differences among EOs which depend mainly on different kinds of variables i.e., composition of soil (physical and chemical), specie of plant used, maturity of plant, time of harvest, expertise used for drying, how the oils are stored and extraction procedure (Bakkali et al. 2008).

It has been demonstrated by Behbahani et al. (2019) that cumin EOs has very promising effect on *E. coli* (Fig. 3A) and *Listeria innocua* (4A). Briefly, in electron micrographs it is evident that the cells without treatment had the typical structure of themselves, displaying a striated wall for *E. coli* (Fig. 3A) and *L. innocua* (4A). In contrast, harmful effects on the structures/morphology of cell membranes have been displayed when cells were treated with the cumin EO at 12 and 24h at the MIC value for *E. coli* (Fig. 3B and 3C) and *L. innocua* (3B and C).

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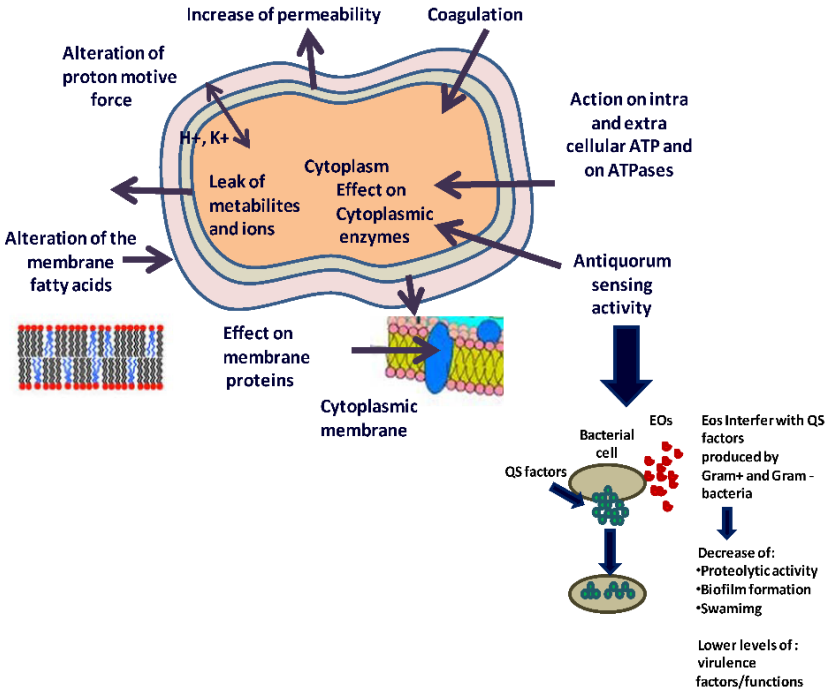

Fig. 1: Possible mode of action and target points/sites of the essential oils on a microbial cell (Nazzaro et al. 2013).

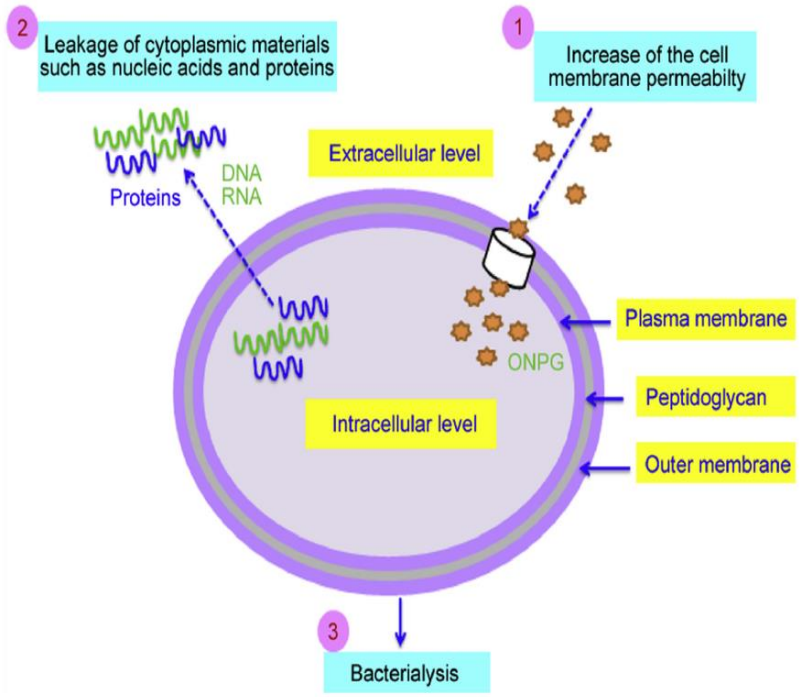

Fig. 2: Bouyahya et al. (2019) have also explained possible antibacterial actions of the EOs of *Origanum compactum* against *E. coli*. They explained that EOs increase the membrane permeability that provoke a disruption in the membrane integrity justified by the release of cytoplasm.

Microstructural level explanations that the cumin EO increases cells permeability and interrupted the cell membrane integrity (Behbahani et al. 2019). Deformed and incomplete shape was seen in treated *E. coli* escorted by the lack of cell walls. Furthermore, cumin EO altered entirely the cell membrane. Also, the shape of the cell was badly altered, and the damaged cell membrane rendered cytoplasm secretion and cell death (24 h at the MIC).

Globally, high environmental temperatures and viral infections have resulted in negative impacts on broiler production. Hence, dietary management, such as the use of natural growth promoters and plant extracts, can surge growth and immune responses though decreasing economic losses from morbidity, deaths and culling (Attia et al. 2017). The use of antibiotic growth promoters (AGP) in animal diets are banned per European Union Reg. No. 1831/2003/EC, which has increased numerous health problems and losses (Attia et al. 2016). Therefore, substitutes to AGP such as prebiotics, probiotics, EOs, and medicinal herbs have become vital (Masek et al. 2014; Hady et al. 2016).

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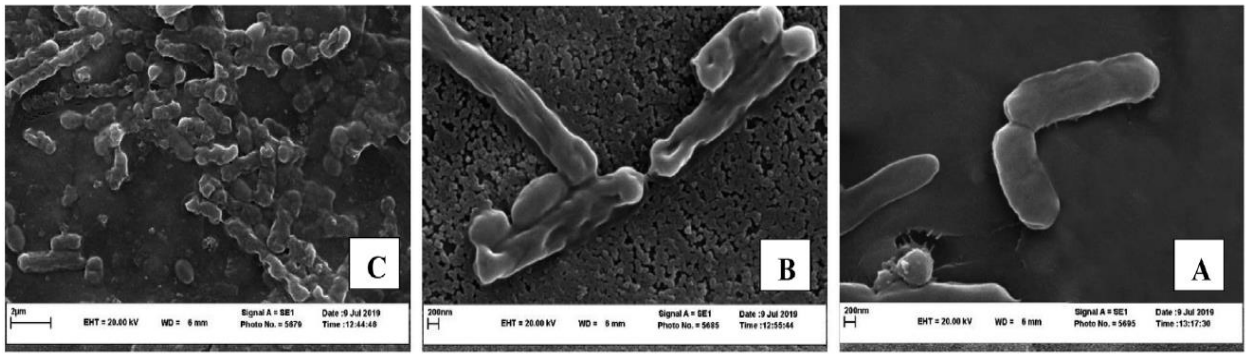

Fig. 3: Micrographs of *E. coli* cells (Scanning electron microscope: SEM): A) cells without treatment; B) *E. coli* cells treated with the cumin EO at MIC value for 12h; and C) *E. coli* cells treated with the cumin EO at MIC value for 24h (Behbahani et al. 2019).

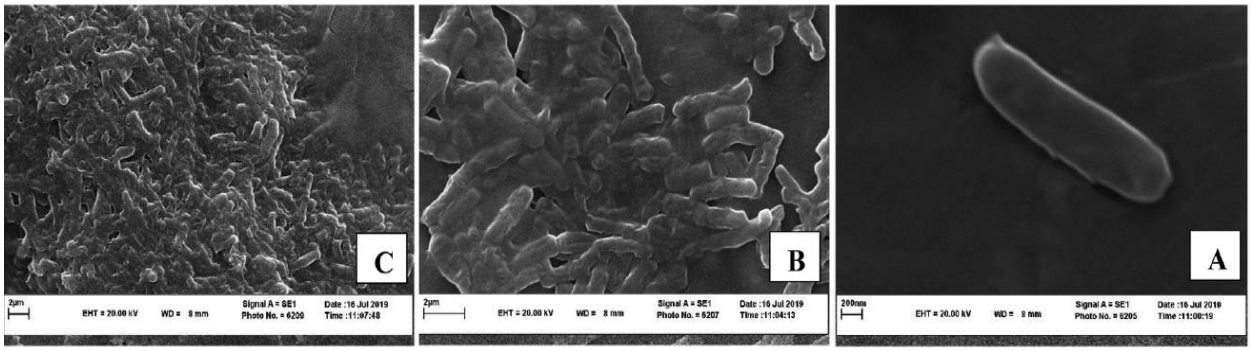

Fig. 4: SEM micrographs of *Listeria innocua* cells: A) cells without treatment; B) cells treated with the cumin EO at MIC value for 12h; and C) cells treated with the cumin EO at MIC value for 24h (Behbahani et al. 2019).

Now-a-days in poultry production, aromatic oils are in practice and used as additives in feed or drinking water due to its broad range of benefits and most of the EOs, which are being used in poultry, have been extracted from onion (*Allium cepa*), cinnamon (*Cinnamomum zeylanicum*), oregano (Origanum vulgare), ginger (*Zingiber offiinale*), eucalyptus (*Eucalyptus*), mountain savory (*S. montana*), fennel (*Foeniculum vulgare*), Australian tea tree, peppermint, lemon balm (*Melissa offiinalis*), garlic (*Allium sativum*), sage (*Salvia offiinalis*), rosemary (*Rosmarinus offiinalis*), turmeric (*Curcuma longa*), thyme (*Thymus vulgaris*), and clove (*Syzygium aromaticum*) etc. (Akbarian et al. 2014; Drăgan et al. 2014; Gopi et al. 2014; Feizi et al. 2014). Keeping in view the so much extensive research on the beneficial effects of EOs, this review has been structured to provide the information on various aspects of EOs usage in poultry production systems which are being discussed in the following sections.

The chemical composition of EOs is very diverse in nature and the main ingredient present can be part of terpenic, aliphatic or aromatic sequence. Usually, EOs comprise of ternion, seldom quaternary compounds. These volatile compounds are made up of esters, phenols, terpenes, aromatics, volatile acids, ketones, and aldehydes etc. It is not necessary that the part of plant which is subjected to hydrokinetics is always processed or treated after harvest (Zerkaoui et al. 2018). Commonly, fresh plants give better therapeutic action and more pleasant scent to solutions apart from lavender flowers, cinnamon and lime flowers which give better results when used dry. When dry plants are used, the lower volatile urine is frequently achieved because of chemical and morphologic modifications as a result of accumulation of grams, heating, air, probably by variation (Hariri et al. 2017; Bozhanska 2018).

Various essential oils used in the treatment or as growth promoters in poultry practice are of onion, garlic, thyme, oregano, aniseed, *Khuzestanica* Jamzad, myrtle, ginger, cinnamon, rosemary and turmeric. Most of these have been mentioned in Table 1.

2. Impacts of Different Essential Oils

2.1. Immunomodulatory effects

Viral infections are main risk to poultry industry and various possible hazards can enhance the threat of it. Immunosuppression is one of those hazards which can be rising from many causes such as mycotoxin, immunosuppressive infectious diseases, vaccine failure and unnecessary use of certain antibiotics and antibiotic

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growth promoters (Galal et al. 2016). Research shows that herbal EOs have positive effects on immune system of broilers as they improve lymphocytic activity, stimulate production of immunoglobulins, and boost up IFN-γ (Faramarzi et al. 2013; Krishan and Narang 2014; Gopi et al. 2014; Adaszyńska-Skwirzyńska and Szczerbińska 2017). The authors perceived that in intestines low number of intraepithelial cells in the proposes possible relaxation of strain ensuing from the GIT defensive mechanism. observed the high levels of IgA have been observed by the addition of 0.5g/kg thyme oil in feed (Placha et al. 2014). Significant increased antibody titers to infectious bursa disease are a good proof for better health due to thyme oil, moreover, higher globulin levels also indicate better resistance for the disease and immune response of bird (Bovera et al. 2015).

One of the commercial products of EO named as (AROMAX®) containing L-Menthol, Eucalyptus oil, Thyme oil and Mint oil was used against respiratory diseases and respiratory problems due to low management of broiler and the experiment showed reduced respiratory signs and improvement in humoral and local immune responses in broiler (Thajel and Ulaiwi 2017). Garlic has capability to augment the level of TNF, interleukins, interferon due to which it has immunomodulatory effect. Moreover, garlic can enhance antioxidant function, antigen presenting cells, and phagocytosis and secretory metabolism of peritoneal macrophages (Hanieh et al. 2010). One of the studies show that the addition of garlic in broiler feed regimens at 0.1% augmented hypersensitivity cutaneous basophilic response, enhanced antibodies response against ND virus and also upgrade the weight of bursa and spleen of broiler (Rahimi et al. 2011).

Another study concluded that a mixture of EOs of *Oreganum aetheroleum* is more effective than ciprofloxacin for treatment of *Escherichia coli* in broiler chickens. Results showed reduction in signs, mortalities, postmortem lesions, enhancement in cell mediated and humoral immune response and bacterial re-isolation (Abd El-Ghany and Ismail 2014).

2.2. Growth Performance, Feed Intake and Feed Utilization

Zhang et al. (2014) explained that volatile oils are considered as growth enhancers in poultry feed due to its growth promoting activity. Scientifically it is attributed as *Origanum vulgare*/*O. heracleoticum* and belongs to family Lamiaceae. Oils of this plant have high number of phenolic compounds i.e., 4.09% thymol and 69.55% of carvacol. Also, cymol, monoterpene hydrocarbons (Mathlouthi et al. 2012). Nieto et al. (2018) studied the effect of oregano EO and designate those birds which were fed Oregano EO was growing faster than that of those fed a Basal diet. Also, when oregano EO was provided from a commercial product named Synergy Essence (500g/ton); peroxidation of lipid was reduced in breast meat (minced) of chicken. Recent researchers showed that when EOs were administered in diet, they reduced the feed intake of broilers and the only possible reason is that EOs possess exasperating smell, which reduces the palatability of feed and bird may refuse to eat (Amad et al. 2011; Bozkurt et al. 2014).

Table 1: Some important essential oils, its active ingredients, and functions

Plant Essential Oil	Scientific names	Used part	Active ingredient	Functions
Aloe vera	Aloe barbadensis Miller	Leaf	Anthraquinones	Anti-inflammatory, immune-modulatory, anti-microbial anti-tumor, anti-diabetic, and antioxidant
Cinnamon	Cinnamomum Zeylanicum	Bark, leaves	Eugenol, phenolic and polyphenolic substances	Astringent, warming, stimulating, carminative, antiseptic, antifungal, antiviral, blood purifying
Garlic	Allium sativum	Bulb	γ-glutamyl-S-alk(en)yl-L-cysteines and S-alk(en)yl-L-cysteinesulfoxides, Alkin	Digestion stimulant, Antiseptic
Coriander	Coriandrum sativum	Leaves and Seed	EO comprised of limonene, carvone, borneol, elemol, geraniol, linalool, camphor, and flavonoids include rhamnetin, quercitin, epigenin and kaempferol	Appetizer, stomachic and carminative
Turmeric	Curcuma longa	Rhizome	Curcuminoids, arturmerone, zingiberene and curlone	Antioxidative, anticarcinogenic, antihepatotoxic, anti-inflammatory and hypocholesterolemic activities
Neem	Azadirachta indica	Leaves	Nimbidin, nimbinine and nimbin	Antibacterial, antifungal, antiviral, anthelmintic, stimulate fiber degrading enzymes, defaunating agent
Rosemary	Rosmarinus officinalis	Leaves	Volatile oil, tannin, bitter substances and resins	Anti-inflammatory, antioxidant
Amla	Embellica officinalis	Fruits	Gallic acid, ellegic acid, tannins, and Vitamin C	Potent antioxidant
Ginger	Zingiber officinale	Rhizome	Camphene, β-bisabolene and arcurcumene	Methane reducing capacity stimulant Gastric

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Cinnamomum zeylanicum bark and leaves are used for treating different diseased conditions. Active compound of this plant is phenolic and polyphenolic constituents and eugenol (Arain et al. 2018). A study was conducted in India by Chowdhury et al. (2018) to estimate the effect of EOs i.e., cinnamon bark oil (CNO), Ajwain seed oil and clove bud oil especially relating to their structures because structures of EO have greater effect in determining the role of EO as an alternative to AGPs for improvement of health and growth of broilers. The results of this study exposed that providing CNO (0.3g/kg) in diet was more beneficial than using antibiotic growth promoters in broiler chicks for improvement of gut health, status of antioxidant, blood cholesterol and immunity. On the other hand, Ajwain and clove oil did not show any considerable effect on immune status and gut health even at greater doses.

Barbour et al. (2011) studied the effect of Mentofin® which is a commercial preparation of eucalyptus-Peppermint EO. This commercial product was used to treat respiratory infection. This treatment was observed very useful in reduction of mortality, improvement of FCR in broiler birds and for elimination of signs and lesions of respiratory infection.

Du and his colleagues in (2016) challenged the broiler birds with *Clostridium perfringens* and supplemented the thymol and carvacol (both 25%) to investigate the effect of EO in intestinal morphology and on immune system of broiler. They concluded that EO has ability to lessen the intestinal lesions, to amend the intestinal histomorphology and to cause decrease in the inflammatory response. Noteworthy progresses were observed in feed intake of birds when 100 or 200mg of thyme and oregano (300, 500 and 700mg/kg) were included in feed (Kirkpinar et al. 2011). Gous (2010) recorded in broilers that the progresses in nutrient absorption and digestibility can cause improvement in growth.

Shomali and Mosleh (2019) reported about a local herb named as *Zataria multiflora* which is found in Pakistan, Afghanistan and Iran and it is used both as an old medicine and condiment. The medicinal herb and its different preparations have also revealed beneficial results in recent experiments of pharmacology. *Zataria multiflora* has also shown useful effects in health of broilers and performance.

Research by Goodarzi et al. (2013) exhibited that onion source can have a valuable outcome on broiler birds by improving its growth performance. When BLJ i.e., blend of encapsulated EOs and organic acids was supplemented, better growth of birds and healthier gut was observed in those broiler birds which were infected with necrotic enteritis and it occurred by establishment of the improved intestinal barrier function, positively modifying the microbiota of GIT and the intestinal immune responses were also regulated. Their results also recommended that addition of blend of encapsulated EOs and organic acids efficiently controlled necrotic enteritis disease after experimental coinfection with Eimeria and *Clostridium perfringens* (Pham et al. 2020).

Research was conducted to know about the effect of oregano EO along with multi-enzyme in protein diet (reduced) in broiler birds of day old. This oil was administered at the level of 200mg/kg in conjunction with multi-enzymes (400mg/kg) which resulted in reduction in mortality, increase in the body weight and better/improved FCR (Dafade et al. 2019).

2.3. Feed Conversion Ratio

Pimpinella anisum L. is the generic name for aniseed plant. It is aromatic and typically found in Pakistan, Iran, Turkey, India, and other countries which are appropriate for the growth of this herb. Its active component is anethole as well as other chemicals i.e., estragole, eugenol, methyl chavicol, and anisaldehyde (Ciftci et al. 2005). When anise EO was added at the rate of 400mg/kg, FCR was shown to be increased by 12% (Ciftci et al. 2005). On the other hand, thyme oil enhanced the food conversion ratio when added at level of 100 and 200mg/kg (Bölükbaşi et al. 2006).

An experiment was performed in broiler chickens for checking the effects of thyme oil. The results showed that the feed with thyme oil at the rate of hundred milligram per kilogram caused noteworthy weight gain, upgraded feed conversion ratio, livability, and turnover in broiler production system (Wade et al. 2018). Thyme belongs to genus Thyme, species vulgaris and family Lamiaceae. It is a medicinal plant and used for spices all over the world. This herb is greatly accepted in dry weathers and hot summer. EO of this vegetation are present in numerous glandular hairs in many forms and formulae and has the property to evaporate when any damage is occurred to its glandular hairs. It causes aroma which is strong in nature and this fragrance is responsible for attracting humans towards this plant which in turn extract its oils for many purposes (Stahl-Biskup and Saez 2002). Thymol and carvacol are main components of this herb and make 20 to 55% of thyme oil extract (Sengul et al. 2008).

Research was planned to show that when 200ppm of extract of oil (cinnamon and thyme) is added in the feed of broiler birds; it significantly increased the feed conversion ratio and weight (live bird) during the period of six weeks. Moreover, it also caused the reduction in ratio of high-density lipid and cholesterol level in blood. Hence it can be verified that oils of herbal plants might be useful for promoting the growth of birds in poultry production and enhance the efficacy of digestive system (Al-Kassie 2009).

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2.4. Antimicrobial and Anticoccidial Activity

Coccidia infection which is caused by protozoan parasite is a serious threat to poultry industry and a great interest is seen to control this disease by using EOs which in turn reduce the intestinal lesions in broiler chicks and a smaller number of oocysts are observed in feces (Barbour et al. 2015; Zhai et al. 2018).

Many *in vitro* studies suggested the antimicrobial activity of essential oils and among these EOs carvacol and thymol have greater antimicrobial activity for pathogenic enteric bacteria like *Salmonella typhimurium* and *E. coli* (Alagawany et al. 2015; O'Bryan et al. 2015). It is noteworthy that Gram -ve bacteria have more tolerance towards the properties of EOs as that of Gram +ve bacteria and it might be possible because of presence of hydrophilic elements in the external membrane (Brenes and Roura 2010; Giannenas et al. 2013; Seow et al. 2014).

When the immune response was amended; concentrations of pathogen was also affected (Diaz-Sanchez et al. 2015). Layer hens showed better antibody titer levels to infectious bursal disease and Newcastle disease when Heryumix was included in their feed (Özek et al. 2011). But in other study of Heryumix, the immune response (humoral) of layer was not enhanced during heat stress (Bozkurt et al. 2012).

Abbas et al. (2017) conducted a study to check the effects of EO *Camellia sinensis* on broilers for coccidiosis and the results were amazing because this oil could cause immunomodulatory property in birds against avian coccidia. The recent study inspected the *in vitro* antimicrobial action of EOs obtained from different plants and herbs like lemon, peppermint, and cinnamon etc. against subspecies of salmonella like *Salmonella enteritidis* and *S. typhimurium* which were already isolated from poultry birds. These essential oils were good for disinfection of sheds but not for treatment. Additionally, these volatile oils prevented the establishment of pathogens in intestine, when added in feed (Ebani et al. 2019).

It was concluded in a study that vital oils of *Cinnamomum zeylanicum and Eucalyptus globulus* have outstanding activity against Salmonella. It is suggested that these plant extracts may be brought into marketing as a substitute of antibiotics for the control and eradication of bacteria i.e., *Salmonellae enteritidis* and *S. gallinarum* in poultry (Yasmin et al. 2020). If we talk about the antimicrobial property of EO; it mainly depends upon many factors like lipophilic property, chemical composition, and functional group of oils. Terpenes are the most prominent feature found in these volatile oils accompanied by hydrocarbons. Cinnamon oil has linalool, eugenol etc. while Eucalyptus oil has carvone, and eucalyptol (Unlu et al. 2010; Gouveia et al. 2012).

2.5. Anti-oxidative Activity

Poultry and its products are predominantly disposed to oxidative stress and deterioration because of their high amount of polyunsaturated fatty acids. Khan et al. (2012) reported that thyme oil is used as oxidant reduction in poultry meat and eggs. This antioxidant activity might be attained by phenolic group of essential oil. The carvacol is another antioxidant nutrient which prevents the broilers from free radicals and hazardous compounds accumulation (Brenes and Roura 2010; Alagawany et al. 2015). Ginger (*Zingiber officinale*) is a rhizomic portion of this plant. It is used as a flavor and medicine too. It has *in vitro* antioxidant activity and antidiabetic (Morakinyo et al. 2011).

Myrtus communis which is from Myrtaceae family and subfamily Myrtoideae) is a medicinal plant which grows annually. Also, consumed for food and spices. Iran, Morocco, France, and some other countries are origin of this magical plant. Flavonoids and tannins are found in the leaves (Romani et al. 2004). The plant *Satureja Khuzestanica* belongs to the same family as oregano and thyme. This is mainly found in Southern Iran where it is used as ethnomedicine. It acts as an analgesic and antiseptic. It also has antioxidant property (Abdollahi et al. 2003).

Nobakht et al. (2017) did an experiment on broilers for a period of 42 days and used an extract of *Zataria multiflora* at the rate of 0.5% of feed. This resulted in reduced concentration of malondialdehyde along with increase of an enzyme in serum known as glutathione peroxidase. It was also observed that when *Zataria multiflora* was included in the diet for last 14 days of rearing, the MDA concentration gave similar results.

In alternative study, Javan et al. (2012) exposed that when broilers were fed with diets comprising 100, 200, and 400mg/kg essential oil i.e., *Zataria multiflora* for about forty-two days decreases malondialdehyde content of breast chicken meat. In a study by Kavoosi and Rabiei (2015), it was shown that thymol rich *Zataria multiflora* EOs exhibited better antioxidant activity. Onion oil was verified to have an antioxidant property with few anticancer characteristics (Ramos et al. 2006).

Another fascinating topic talks about the antioxidant traits of different EOs in chicken. It is seen that these EOs cause the reduction in peroxidation of lipids in the muscles of poultry (chicken). Thigh muscles are more prone to oxidation because of the high level of fatty acids (polyunsaturated). The oxidation of these Fatty acids yields malondialdehyde, peroxides, oxysterols, and lipids (Tongnuanchan and Benjakul 2014). Rosemary belongs to the family Labiatae which has genus *Rosmarinus* and *spp. officinalis*. This herb has maximum antioxidative action (Estevez et al. 2007). Some of the most significant biological chemicals extracted from this plant are rosmarinic acid, carnosol, antioxidants carnosic acid and camphor (Alagawany et al. 2017).

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2.6. Non-antimicrobial of EOs in Poultry

Now-a-days, EOs have been used in poultry for getting benefits for non-pathogen settings (Diaz-Sanchez et al. 2015). In one study when EOs were added to poultry feed; its digestibility was amended (Williams and Losa 2001). A commercial mixture of EOs is available known as CRINA® (Switzerland) which contain piperine, thymol and eugenol and when this blend was fed to broiler birds at level of 50mg/kg; level of trypsin, maltase and amylase was shown to be improved as compared to control (Jang et al. 2004; Jang et al. 2007).

2.7. Anti-viral Effects

Awaad et al. (2016) investigated a study on broiler chickens and concluded that the EOs mixture of peppermint and eucalyptus has controlled velogenic Newcastle disease virus vVND disease in a significant manner and it was found to enhance the immune response against this challenging virus which is causing great distressing economic effect on poultry production system.

Their efficacy in modifying the immune system of compromised birds after giving infection with Infectious Bursal Disease Virus and vaccination for Infectious Bursal Disease Virus as compared to control groups (untreated) was also obvious (Awaad et al. 2009; Awaad et al. 2010). Another study (Saderi and Abbasi 2011) reported that adenoviruses can be controlled by the used of thyme oil. Oregano oil along with its component "carvacrol" have been proved to be advantageous against Rotavirus (Pilau et al. 2011; Gilling et al. 2014) and enteroviruses (Sánchez et al. 2015). Ma and Yao (2020) have reviewed possible action of essential oils on the viral lifecycle (Fig. 5). According to them, viruses attach, penetrate, and enter the host cell, where genetic substances are replicated, followed by the creation and release of new virions (Schnitzler et al. 2010). EOs affects the virus particles at intercellular (absorption/binding) as well as intracellular (at penetration, uncoating, genome replication of viruses) stages for inhibition of the viral infectivity.

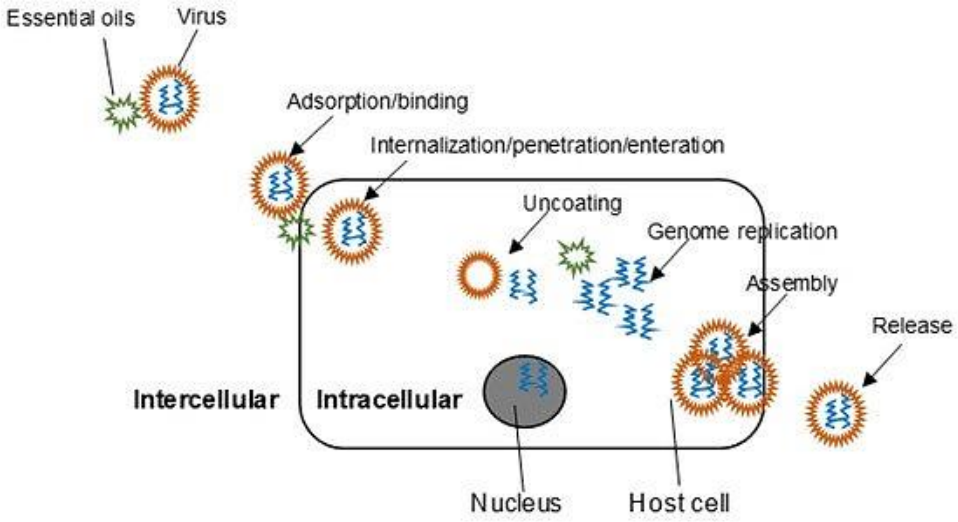

Fig. 5: Possible targeting sites of essential oils during viral lifecycle (Ma and Yao 2020).

2.8. Effects of Onion and Garlic Oils

Onion and garlic both belong to same genus Allium and many studies have improved that these both have important role in treating innumerable diseases. They are full of quercetin and compounds of sulfur. Onion belongs to Liliaceae family and has scientific name as *Allium cepa*. It is full of copper, magnesium and potassium and comprises of traces of sugar, vitamins, and fat (Gabor et al. 2012). Garlic contains high levels of potassium, phosphorus, zinc, and sulfur; medium concentration of vitamin A and C as well as selenium; and low levels of sodium, magnesium, calcium, manganese, iron, and B-complex vitamins. In addition, many compounds have been identified and isolated from garlic extracts including 33 sulfur compounds (Agarwal 1996). Garlic belongs to species *sativum* and is used as a spice in foods as well as a medicine for several years (Hanieh et al. 2010).

A data was presented about the effects of onion and garlic oils in quail and showed that onion oils act as good product for reducing the level of sugar in blood and body weights. It is also recommended that oils (onion) lower the risk of heart diseases. There are variable studies on the effects of garlic extract as a hypoglycemic role so more work and research are required to know about the facts (Abduljabbar and Abdoulrahman 2018). Garlic is beneficial treatment for different kinds of medical illnesses and is full of bio actives compound. Garlic comprises an amino acid

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having sulfur called S-allyl cysteine. It has a crucial part to act as an antioxidant (Saravanan and Ponmurugan 2010). Derivatives of garlic have proved that it is responsible for good feed conversion in broilers. Also, the height of villi (small intestine) is increased which in turn increases the absorption (Fadlalla et al. 2010).

2.9. Effects of Essential Oils on Ectoparasites

Different synthetic insecticides are in practice to control the problem of ectoparasites. However, their regular usage can cause several other problems like development of resistance, public health concerns particularly in terms of food and water residue and environment pollution. Essential oils are quite competent green alternate of insecticides (El-Seedi et al. 2017). It has been proved by the researchers and the scientists from all over the world that EOs and phytochemicals are effective against ectoparasites. Moreover, they have ovicidal, larvicidal, adulticidal and repellent effects as well (Abbas et al. 2018).

Different essential oils are found quite competent against a range of ectoparasites, particularly lice, mites and ticks. Their efficacy has been proved by different exposure routes like immersion and physical contact with EO treated surfaces, even their trace amount (vapors) was found very efficacious in spray formulation (Bakkali et al. 2008). Generally, the insecticidal activity of these oils can be attributed to their neurotoxic and suffocative effect against parasites. For example, terpinen-4-ol is a monoterpenoid found in tea tree oil at high concentration, inhibited the arthropod acetylcholinesterase, an enzyme essential for transmission of action potentials (Lopez and Pascual-Villalobos 2010). In addition to this neurotoxic effect, the hydrophobic nature of the oils may also employ the mechanical effects on the parasite which may result in disrupting the cuticular waxes and blocking their spiracles, which leads to their ultimate death (Burgess 2009).

Poultry red mite (*Dermanyssus gallinae*) it is not only the ectoparasite of laying hen but also cause restlessness, irritation, anemia and stress in broilers, wild and aviary birds (Tabari et al. 2020). EOs from different plants sources has been used against *Dermanyssus gallinae* and considered as an effective treatment against this infection. Most commonly used EOs against poultry red mites are of Coriander (*Coriandrum sativum*), clove (*Eugenia caryophyllata*) and cade (*Juniperus oxycedrus*) (Abbas et al. 2018).

Some other ectoparasites in chicken like *Menopon gallinae* (chicken lice) and *Ornithonyssus bursa* (mite) are of great economic significance in poultry. Although they do not cause death directly, but they surely are the cause of itching, weakness and lower egg production in case of layers. This parasitic burden has been controlled to a greater extent by the EOs from citronella (lemon grass) and Ginger. Chemical constituents and active ingredients in citronella (citronellal) and ginger (terpenes and oleoresin) are mainly responsible for this effect (Vigad et al. 2021).

2.10. Anti-inflammatory properties

Terpenoids and flavonoids which are components of essential oils are known to have anti-inflammatory features and these properties reduce the absorption of prostaglandins (Krishan and Narang 2014). It is observed that other compounds which are found in EOs have pain reducing, edema relieving and anti-inflammatory characteristics e.g., 1,8-cineole (found in eucalyptus oil) and linalool from lavender oil (Peana et al. 2003). Other examples of plants which possess anti-inflammatory potential are anise, chamomile, liquorice and marigold (Srinivasan 2005). Turmeric is also called as *Curcuma longa*. Rhizome is the basic part which is used. Its active ingredients are curlone, curcuminoids and zingiberene etc. Major functions of this herb are in antioxidation, as well as anticancerous, antihepatotoxic and anti-inflammatory (Vinus et al. 2018).

2.11. Anti-fungal Properties

Volatile oils mixtures and their blends also responsible for displaying antifungal activity (Owanagh et al. 2010; Hood et al. 2010). Possible mechanisms of action of antifungal bioactive compounds in Star anise essential oil (SAO) has been described by Dwivedy et al. (2018), Neto da et al. (2019) and Yu et al. (2021). According to them, SAO leads to destruction of cytoplasmic membrane, the degradation of the cell wall, or denaturing of membrane proteins those results in ions, protein, DNA and lipid damage, glucose leakage, and finally cell death (Fig. 6). There are numerous antifungal bioactive compounds (phytochemicals) in SAO such as Trans-anethole and (R)-(+)-limonene against *Aspergillus flavus* (Aggarwal et al. 2002; De et al. 2002), Limonene against *Trichophyton rubrum* (Chee et al. 2009) and α-pinene and Linalool against *Candida albicans* (Cosentino et al. 1999).

Hammer et al. (1999) described the action of monoterpenes which are very beneficial against fungi and yeast. These plant oils are also found to be advantageous for different molds relating to genus *Aspergillus* i.e., *Aspergillus fumigatus* which is responsible for causing aspergillosis in poultry birds (Esper et al. 2014). It is proposed by Esper et al. (2014) that oregano oil can be include in feed safely for reducing the effects of aflatoxin B1. In a study, effect of tea tree EO was determined for controlling the fungal diseases and it turned out to be best for eliminating the effect of fungus i.e., *penicillium* in lentils and grapes (Chidi et al. 2020).

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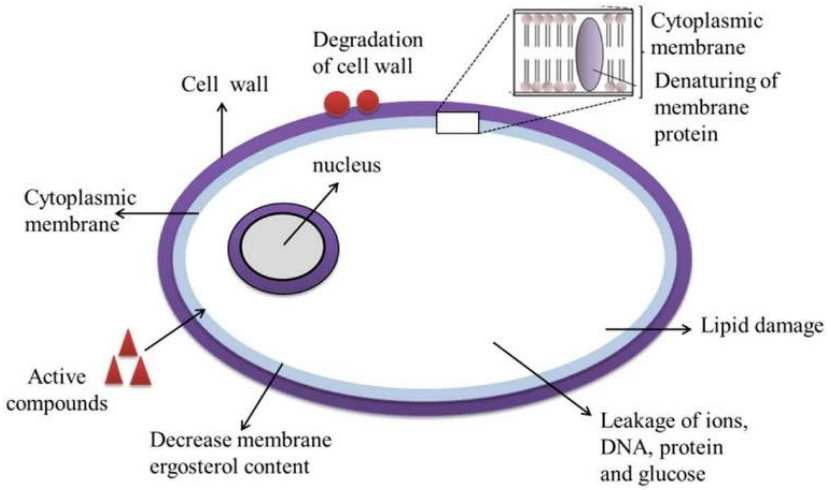

Fig. 6: Probable mechanisms of antifungal bioactive compounds in star anise essential oil (Dwivedy et al. 2018; Nato et al. 2019).

2.12. Effects on Digestive and Respiratory System

Avian gastrointestinal system is positively affected by EOs because they support the system to reestablish the balance of microorganisms and upsurge the absorption of nutrients, which may primarily be ascribed to terpenoids. These oils are very good for increasing the feed conversion as described previously (Barbour et al. 2010; Mountzouris et al. 2011).

Digestive enzymes are also produced in high quantity which result in improved absorption of nutrients and digestion. Pepsin and HCl is secreted in large amount so the better digestion of protein is accomplished (Gopi et al. 2014). Moreover, taste and smell of those substances which are present in EOs also play a vital role in the gastric juices and saliva secretion. Though, some oils cause irritation to the mucus lining of gut which then cause inflammation. It is vital, thus, to properly select and compose dose of EO.

A recent experimental study was performed to check the effects of blend of different EOs and organic acid on intestinal villi, growth of birds, blood values, and bone length of leg in broilers (Ross). A commercial feed additive was used named as Avi-protect®. In conclusion, development in intestine was seen and there was improvement in growth and metabolism of lipid in birds under study (Liu et al. 2019). Furthermore, it is suggested that thymol oil has the capability of protecting the intestinal microvilli which are accountable for the nutrient absorption, also inducing positive effect to secrete the endogenous enzymes which are consumable and prompting blood elements (Hashemipour et al. 2013).

As far as uses of EO for respiratory system is concerned, eucalyptus and peppermint oils cause the thinning of mucus so it can be easily removed from the air passages. Other oils like methanol and eucalyptol have expectorant and antispasmodic effects in host. Consequently, breathing becomes easy at the time of inflammation due to clearance of air passages (Durmic and Blache 2012).

In poultry houses, respiratory problems occur mainly during summer season because of rise in temperature and low level of humidity which in turn cause the surge in dust air. Under this type of circumstances, respiratory tract infections become more usual and severe in broiler birds due to deposition of different particles. Medicines proposed to treat the respiratory illnesses contain different oils like thyme oil and its major constitutes i.e., carvacrol and thymol. Such oils are very useful for stimulating the respiratory system and are good for smooth muscles (Edris 2007).

2.13. Other uses of Essential Oils (egg quality/biochemical/hematological)

A motivating study by Witkowska and Sowinska (2013) displayed improvement in sanitation conditions in poultry house through air sanitizers by means of thyme and peppermint oils independently as main components. An interesting study was done to explore the outcome of 7 levels (0, 25, 50, 100, 200, 400 and 600mg/kg) of plants feed additive comprising a combination of different EOs from black cumin, thyme, rosemary, fennel, and anise on growth performance of layer chicks, quality of eggshell, biomechanical characteristics and mineralization of bone in egg-laying fowls. The study was concluded by the fact that providing EOs in diet with a low or medium concentration has improved parameters involving bone, although at exceeding levels these values were badly affected in laying birds (Olgun 2016).

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The addition of EO combination @24mg/kg of feed caused significant improvement in production of eggs, efficiency of feed and it was also observed that the percentage of cracked eggs was reduced (Cabuk et al. 2006). A recent experimental study was performed to examine the positive or negative effects of housing systems and the inclusion of EOs (rosemary and cinnamon) on egg quality and performance of layer birds. Housing systems were cage and floor type while three kinds of oils i.e., zero, three hundred milligram per kilogram of rosemary, 300mg/kg cinnamon were used to check their effects on blood biochemistry, hematology, egg quality, status of immunity, oxidative level, and production of layers. The positive effects were observed on performance and quality of eggs whereas housing types did not cause any notable change in these characteristics. Parameters like level of blood cholesterol, ALT, AST, feed conversion, Ca, P, immunity, antioxidant, intake of feed, urea were found to be significantly higher and improved in treated groups (with EOs) as compared to control (Abo Ghanima et al. 2020).

A 42-days trial was conducted, and lavender oil was given in feed at the rate of 300 and 600mg/kg. Results showed that at level of 600mg/kg lavender EO, there was improvement in gut bacteria, growth rate and intestinal mucosa. Antioxidant status was better at both levels in serum and liver.

Dietary lavender EO is a better replacement for AGPs for increment of production (Barbarestani et al. 2020). A recent study proposes that essential oils which are excavated from the oranges could also be used as preserves for chicken meat. This type of method reduces the oxidation of lipids in meat (chicken) without changing the color, flavor, pH and quality (Rimini et al. 2014).

An experimental study was conducted to examine the effects of thyme and its EOs in diet. Three levels of thyme were used i.e., five, ten and fifteen milligram per kilogram and its EOs were used at different levels of 0.5, 1.0 and 1.5g/kg on antioxidant status, blood picture, growth performance and immune response in broiler chickens. This study proved to be very advantageous for different parameters of chicken (Ismail et al. 2019). The central active ingredient of thyme (aromatic plant) is thymol which act as phenolic part and is usually known to be utilized as antiseptic agent (El-Ghousein and Al-Beitawi 2009; Toghyani et al. 2010).

An experiment was conducted to assess the histopathological lesions, hematology and liver function of broilers which were given feed added with EOs e.g., *lippie rotundifolia* and lemon grass. MCV and MCH were found to be significantly lesser in negative control group (broilers). Hyperplasia of biliary duct and fibroplasia were detected in all groups with higher scores of histopathology in those broilers which were supplemented with *L. rotundifolia* oil (Santos et al. 2019). EOs of lemon grass and *Lippia rotundifolia* are also used as substitute for increasing the performance because of their antimicrobial property and are suitable for stabilizing diet (; Souza et al. 2015; Assis et al. 2017; Azevedo et al. 2017).

The current study was designed to evaluate the beneficial effects of anise, powder of curcuma seeds and fenugreek (at different levels) by feeding broiler chickens. Feed efficiency, productive performance, carcass features and few blood elements were also estimated. The results exhibited the significant effects and improvement in the FCR, live body weight and total gain, Although, the consumption of feed was not affected by the nutritional addition of these oils (Amein et al. 2019).

When the curcumin was added in feed; it regulates the secretion of bile acids and was responsible for increasing the different enzymes activity like protease, lipase, and amylase which in turn enhance the metabolism and digestion (Platel and Srinivasan 2000). Liver function also gets better by curcumin which lessens the levels of glucose in blood, triglycerides, and LDL cholesterol (Seo et al. 2008; Gandhi et al. 2011).

In a study, ginger powder was used as a natural source for improvement in growth, characteristics of carcass and the blood profile of birds (day old broilers). The dose levels were used as 0, 0.2, 0.4 and 0.6% in this experiment. The results of this study showed that there was no significant difference in weight gain of birds among different groups. However, the feed conversion ratio was better than control group. Biochemical values and hematology showed no obvious differences in dose receiving groups. So, it was determined that levels of ginger which was used in this experimental trial was not sufficient to promote the growth of chicks (Hassan et al. 2019).

Usually in broiler diets, soybean oil is used but in this experiment this oil was replaced with linseed oil (rich in omega 3) and the extract of pomegranate peel was used. Different parameters like lipid profile, fatty acids constituents, performance of birds, flavonoids and phenols were checked. Body fat was reduced due to addition of PPE and linseed oil in diet. Level of total cholesterol and triglycerides fatty acids in serum of broiler chicks was also observed at low level because of linseed oil. Providing PPE in diet enhanced the phenol and flavonoid in chicken meat (Kishawy et al. 2019).

In another study, Oregano EO was given in the feed of laying hens (commercial) to know the facts regarding this oil. The aim of this study was to check the changes in biochemical profile which were associated with liver function and metabolism of lipid and protein. Oregano EO was used @ 0, 50, 100, 150 and 200mg/kg of feed. Level of globulins and proteins was high in those groups which received dose at the rate of 150 and 200mg/kg (Migliorini et al. 2019). Also, high level of fifty-six oregano EO was responsible for increasing the cholesterol (serum levels) in broiler chickens (Basmacioglu Malayoglu et al. 2010).

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3. Essential Oils Limitations

There is no uncertainty that EOs have vast range of uses but they are also responsible for causing toxicity and unwanted effects in host (Yang et al. 2005). These volatile oils weaken the structure of cell membrane and cell wall as well as membranes of cytoplasm and cell organelles such as peroxisomes and mitochondria (Bakkali et al. 2008). EOS interrupt the mitochondrial membrane, so it causes problems in depolarization in cell via changing ion channels which in turn effect the synthesis of ATP (Vercesi et al. 1997). EOs for example thymol and carvacol have been demonstrated as toxic for the mucosa layer (intestinal cells) because of lipophilic and hydrophobic characteristic (Giannenas et al. 2003). Additionally, EOs separated from Chinese and Egyptian vegetations have been stated to produce fumigant toxicity (Fu et al. 2013). It should also consider that essential/volatile oils and their byproducts could cause hypersensitive reactions and symptoms (De Groot and Schmidt 2016).

4. Future Perspective

It is observed that environment plays an important role in poultry production. There is a correlation between environment and effects of volatile or EO and it is the need of time to thoroughly investigate it. As far as the properties of EOs are concerned, the immunomodulatory and anticoccidial activities have gained more importance and attention. The chemical structures of EOs should also be thoroughly studied to acquire the more beneficial effects from EOs.

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